Space,Time, and Becoming

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José Croca · Pedro Alves · Mário Gatta

Space, Time, and Becoming

Cátedra *A Razão*
Faculdade de Letras da Universidade de Lisboa
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AUTORES: José Croca • Pedro Alves • Mário Gatta

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Introduction

Space, time, and becoming are, and have been for thousands of years, basic fundamental concepts for the understanding of our inter-relationship with Mother Nature. The Greek thinkers have dealt with some aspects of it. Indeed, for some schools of thought motion was an illusion of our senses while for others, on the contrary, everything was in permanent motion. With the rise of modern science, mainly in the sequence of the work of Galileo and Descartes, Newton established the basis of Classical Mechanics for which he first needed to assume the concepts of absolute space and absolute time.

This state of affairs, where absolute space and absolute time ruled, remained foundational in physics and in other sciences till the beginning of the twentieth century. Since then, and due to the enormous development in the experimental ways for probing Nature, the traditional concepts of space and time no longer reveal themselves adequate to account for the new empirical phenomenology.

Einstein, fully immersed in the linear Cartesian method, embraced the concept of spacetime, implying a linear relationship between space and time. Also, in the field of microphysics, and in order to deal with the wave-duality mystery characteristic of the quantum phenomena, Bohr proposed his principle of complementarity. The mathematical form of this principle is given by the Heisenberg uncertainty relations which are deeply rooted in the Fourier ontology. As a consequence of this ontology a quantum entity occupies all space and time.

Now about a century later, and mainly due to the collective work of the Research School of Lisbon, we try to analyze these basic concepts of our understanding under the light of a new ontology. In the traditional approach - the Cartesian linear way - the whole is equal to the sum of the parts, which are assumed to be perfectly independent and without alteration. The new approach, extending and developing some early ideas of de Broglie's along novel avenues, assumes that the whole, which emerges from the reciprocal inter-dependence among the constituent parts, is much more than their simple linear sum. This occurs because, in our view, the constituent parts that contribute to make the whole, due to theirs reciprocal interaction, change themselves in a greater or lesser degree. Not independence but inter-dependence. Still, in a certain sense we could say that the linear approach is a simple particular case of the complex emergent way when the change among the making parts is negligible. In these circumstances the parts may be treated as independent.

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Chapter 1

Physics of the Becoming

J.R. Croca
Departamento de Física, Faculdade de Ciências; Centro de Filosofia das Ciências, Universidade de Lisboa Campo Grande Ed. C8, 1749-016 Lisboa Portugal
(croca@fc.ul.pt)
and
M.M. Silva
Centro de Filosofia das Ciências, Universidade de Lisboa Campo Grande Ed. C8, 1749-016 Lisboa Portugal
(nefertari.horus@gmail.com)

1.1 Abstract

Some concrete experiments shall be presented showing that the traditional assumed fundamental concepts of space and consequently the chronological time, that is the time of the clocks, are not basic categories of our understanding. On the contrary, they are nothing more than mere common notions that at our habitual scale of description of reality have proven relatively adequate. Still, even if these concepts were and are very useful at their scale of description, nonetheless they, by their very nature of human constructs, impose restrictions to the next development for the understanding of Nature. Due to the recent expansion of the New Physics, the Hyperphysics, and correlated experimental evidence, these traditional concepts have shown indeed their limits of validity clearly indicating the necessity to look forward a new basic form of knowledge free or, at last, not so dependent on the traditional and limiting concepts of space and chronological time.

Keywords: Becoming, time, space, Hyperphysics, subquantum medium, principle of eurhythmy, complex interaction, emergence, de-emergence, tunneling, teleportation.

1.2 Introduction

In this work we intent to show that space and the correlated chronological time are indeed nothing more than secondary derivable concepts, human constructs, which have already shown their limits of utility for increasing our understanding of Nature. Furthermore, we aim to present a first tentative project for version of Physics without space and chronological time, or at least a proposal were these concepts play a minor role.

Naturally we are fully aware that all our interpretations of the reality that is, our science, is till now based upon the conceptual tools of space and correlated chronological time. Furthermore we acknowledge that without those concepts our present conceptual, formal and technological development would not be possible. Without them our present way of life would be impossible. Still, as any tool, even the best tools, they have their utility but even more important they do posses their own inherent human limitations.

Anyway, in a previous work [1] we have already shown that the concept of time is primordial that is, more fundamental than the concept of space. Now our aim is to go a little further.

To accomplish this task of showing that the conceptual tools of space and the related chronological time are definitely reaching their limits of adequacy to describe Reality we shall first discuss a seemingly very weird experimental fact, the tunneling effect, from its genesis in the field of optics to its extension to the quantum mechanics. From a mere laboratory curiosity this apparently strange effect has nowadays large technological applications namely in the so-called super-resolution microscopes [2], which working process is based precisely in this effect. In addition to these apparently awkward facts another strange experimental discovery connected with the tunneling effect and coming out form the most recent experiments showed the possibility of attaining in practice superluminal velocities [3] that is, velocities greater that c = 300 000 km/s, the velocity of light in the so-called vacuum.

In order to understand these problems and put them in proper perspective we shall present, in its fundamentals the New Physics [4], the Hyperphysics, putting an emphasizing in the ontology in which is founded. From the nonlinear master

equation we shall derive a beautiful solution where de-emergence and emergence of complex physical beings came out naturally. Furthermore it will be shown that the transit time that is, the time interval between de-emergence and emergence as nothing to do with space.

Also we shall present briefly what is called quantum teleportation and make the analogy with the same concepts so dear to the scientific fiction literature.

Having gathered the most relevant scientific facts coming out recently from sound experimental evidence we shall derive the natural conclusions implicit in them. We have to assume that space and the chronological time are not in reality the basic concepts required to help us in getting a true understanding of Reality. In order to go beyond we need to do without them! Task, which, of course, is not easy due to the fact that, for all practical purposes, we all are space addicted.

We know quite well that all our ways, our language, our progress as species to the present stage of development, were deeply molded by the concepts of space and chronological time. Chronological time is nothing more than a link between space and the primordial concept of Becoming of Changing. It is basically a measurement done with the help of space, the position of the handles of a device, the shadow of a rod, etc. So, chronological time is ontologically quite different from Time in the sense of Becoming. Chronological time, the time of the clock, is polluted by the concept of space therefore cannot have the same basic ontological status of the Becoming, of the true Time. Still, here and there, inside and outside, near and far, that is spatial manifestations, are indeed very basic processes, very important conceptual tools that have helped mankind to attain the present level of understanding of Reality. So, to pass without them is not any easy task.

1.3 Tunneling

Sometimes Nature surprises us in the most unexpected ways. It was just what happened with the so-called total internal reflection. When Newton was studying the total internal reflection he discovered that even in conditions of total internal reflection there were some light that under certain bizarre conditions could be observed in the forbidden zone. That is, even if every experimental indication seemed to show that no light would be observed in the transmission medium indeed some small amount of it was in reality detected. Only at the end of the nineteen century this strange phenomena was theorized with the help of Maxwell electromagnetic theory.

To this strange and elusive wave, observed in the forbidden region, was given the

name of evanescent wave. Still, initially this odd wave was only a vague theoretical curiosity. In reality, it was only in 1910, that Schaefer and G. Gross [5] were able to study experimentally the properties of such weird waves with radiation in the centimeter range incident on paraffin prisms. More recently, 1966, Coon [6] made the experiment with visible radiation. Today, the evanescent wave, coming out from total frustrated internal reflection with light, is widely applied in up today technologies namely touch screens and so.

In quantum mechanics it was Gamow [7], 1928, the one who showed that alpha emission by radioactive nuclei could also be explained in terms an effect akin to the total internal reflection, named from then on the tunneling effect. Still, this tunneling effect even if theoretically very interesting was for about half a century no more than a mere exciting laboratory curiosity. This state of affairs changed radically when in eighties of the last century due to the work of two IBM researchers, Binning and Roher [8] who produced the prototype of a whole new generation of super-resolution microscopes based precisely in the tunneling effect with electrons.

This type of new imaging technology was next extended to the optical domain by Pohl and its group [9]. As expected, this new imaging technology underwent a very fast development and now we have scanning super-resolution optical microscopes with a resolution power hundreds of times greater than those of the common Fourier optical microscopes. Presently the most advanced imaging systems are based exactly on this apparently strange tunneling effect. These super-resolution microscopes are now common imaging devices in any well equipped laboratory.

By now it is perfectly clear that tunneling effect and total internal frustrated reflection are nothing more than a consequence the wave nature of the complex particles either microscopic or not.

1.3.1 Total internal reflection

A beam light coming from a point source incident on the surface separating two optical media gives origin to two beams of light: One is the reflected beam, the other is transmitted one. Being that the angle of incidence equals the angle of reflection while the angle of transmission is given by Snell's formula,

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

as shown in Fig. 1.1

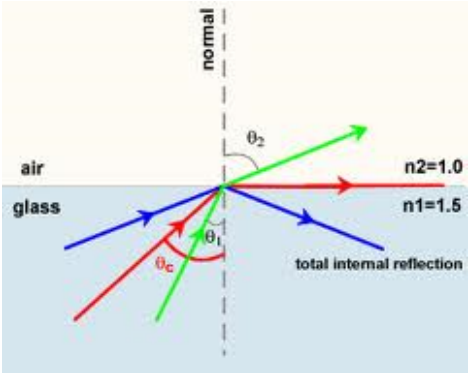


Figure 1.1: Reflection of the light in two optical media from glass to air

Next photo, Fig.1.2 shows an example of the total reflection of in the surface glass-air.

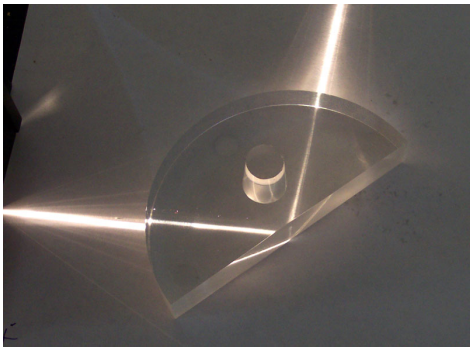


Figure 1.2: Total internal reflection glass-air

As can be seen, for incident angles greater than the critical one, in the transmitted medium, the air, no transmitted light is observed. Still, if we probe this forbidden zone carefully with, for instance, the help of a glass prism, an evanescent wave may indeed be observed.

1.3.2 Super-resolution microscopes

The imaging history is deeply connected with the enlarging of very minute objects. That is, with the problem of seeing very small objects which under usual conditions with naked eyes were completely unobservable. We know that certain

Sumerian tablets were written in such a way that today only with a magnifying glass it is possible to read them. On the other hand we also know that Romans had some kind of magnifying glasses. Still it was only due to the appearance of the work Optics, written by Kepler in 1604 that, in the paraxial approximation, valid for small angles of incidence, the theory of the imaging devices was known. Anton Van Leeuwenhoek of Holland (1632-1723) was one of the first in the field of microscopy and one of the greatest of all times even if he used very rudimentary devices. As the technology improved better microscopes were made till this way of imaging reached its maximal inherent capabilities. This maximum power of resolution was theoretically discovered by Abbe, a physicist, at about the end of the XIX century. He was able to show that the theoretically maximal resolution of a common microscope, now called Fourier microscope, is given by about half of the wavelength of the light used. It is precisely because of the dependency of the resolution power of a microscope, on the wavelength of the light that is, the dependence on the color, that that blue ray technology is now being developed. Since the blue light is about half the wavelength of the red light, used in the more old devices, it means that the resolution using blue ray technology is about twice greater. This means that, in each pixel we are now able, using blue light, to place four pixels of information.

In order to overcome this theoretical limitation of about half wavelength, in the early eighties two IBM researchers Gerd Binning and Heinrich Roher [8] devised an entirely new way of imaging. Since they were more concerned with technology they do not pay much attention to the limitations which according to the orthodox interpretation of quantum mechanics were absolute since they were deeply connected with Heisenberg relations. Again we have an example were the practice, the experimentation, that is, Nature surprises us and goes far beyond the so-called human theoretical impossibilities. Indeed, it seems like a curse. Every time human tries to put, to construct an absolute boundary, a barrier, an in principle impossibility, the future developments of science have show how naive that pretention was. Binning and Roher named the new imaging device by scanning tunneling electron microscope. Later, in 1986, they received the Nobel Prize for this discovery.

Pohl and is group applied the ideas of the scanning tunneling electron microscope to the optical domain and gave origin to a whole panoply of imaging devices able to explore the optical properties of the samples. The first of these optical imaging devices was developed by Pohl et al. in 1984 with a resolution of about ten times greater than the usual Fourier microscopes, that is $\lambda/20$. Today the resolution of the most common scanning optical microscopes is of about 10 nm, which for a $\lambda = 633$ nm corresponds to a resolution of more than $\lambda/50$. Although the

determination of the true resolution of these devices constitutes a very arduous problem, some authors claim the possibility of attaining, with special illuminating systems, spatial resolutions of the order of 1nm which, for the same wavelength, gives a ratio of about $\lambda/500$.

1.3.3 Superluminal velocities

Quantum mechanical calculations give unexpected results when applied to tunneling. Apparently they seem to indicate that the crossing time inside the tunneling barrier is zero. Still one must be cautions and not haste to unsupported conclusions. Mostly people, even those who had the obligation of knowing, seem to forget that orthodox quantum mechanics is not only a non causal theory but even more it is indeed an undeterministic theory. Consequently trying to find a common causal description that is, a description in time and space, for a given phenomena is completely out of the orthodox quantum program. As consequence of Fourier ontology, upon which the formalization of Bohr's complementarity principle and consequent Heisenberg underterministic relations are based, orthodox quantum mechanics is a theory in which any quantum entity previously to measurement is spread over all time and space. That is, is omnipresent in time and space. When the measurement is done, due to the consciousness of the observer, only one out of the multiple possible potential states actualizes itself.

Experiments done over all the world have shown, using a causal way of thinking, that it is possible to send a signal through a physical barrier in tunneling conditions traveling faster than the light in the said vacuum. Indeed Nimtz [3] and his group at the University of Cologne reported that they have sent through 12cm tunneling barrier Mozart's 40th Symphony at 4.7 times the speed of the light.

Everybody agrees with the results of these experiments. The question is if they imply a real superluminal velocity or not? All calculations are done under Fourier nonlocal and nontemporal ontology claiming that only the infinite in time and space harmonic plane waves do have a perfect frequency, a pure velocity. In these circumstances it is very difficult, if not even impossible, to tell which is the velocity of a finite wave. In the nonlocal orthodox quantum mechanics only the infinite harmonic plane wave has a "true" velocity and therefore a pure a perfect frequency. All other finite waves are no more than combinations of these infinite waves. Consequently, any of these finite waves has, in principle, as many velocities and frequencies as the number of harmonic plane waves that make it. Since these harmonic plane waves are spread over the whole space and time, his hard to tell, in this paradigm, which is the velocity of a finite wave. Since the harmonic components that make the pulse fill all space and time, practically anything is

possible. The weirdest things are then possible like for instance retroactions in time. That is, a pulse may arrive at a destination prior being produced by the source! Situations of this kind are not new in physics. We have just to recall the prediction and description, in geophysics, of earthquakes. The use of Fourier analysis implies, in certain cases, that the seismic pulses arrive before the actual earthquake took place. Other times the precursors started before the formation of the Earth itself! Since geophysicists are people facing everyday practical concrete problems, they need to have their feet placed on solid ground. So, they discard, as a nuisance, these aberrant situations resulting from the abusive use of Fourier global paradigm. It was precisely to avoid these irregular situations, that the geophysicist, Jean Morlet, created the concept of finite wave from which wavelet local analysis sprout [10].

Because these observed superluminal velocities went against Relativity claims many authors argue that those experiments did not undermine the statements of the theory. Indeed, by accepting Fourier ontology and by a careful tailored redefinition of the velocity of a finite wave it is possible to "prove" that no signal travels faster the light.

Let us now analyze the essential of these type of experiments in order to be able to make a safer judgement. See next Fig. 1.3

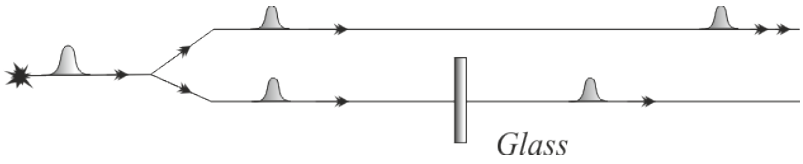


Figure 1.3: The pulse of light crossing the piece of glass arrives after the one which goes through the air.

The source emits a luminous pulse which is then divided into two pulses, each of them traveling an equal extension. In one of these paths, the one above, the light only crosses air. In the other path, somewhere in the middle, we place an optical medium, a piece of glass for example. We can verify, through this experiment, that the luminous pulse traveling through air reaches the target detector before the one which crosses the optical medium.

From this observed fact, the posterior arrival of the pulse crossing an optical medium, a piece of glass fibre, for example, everyone may correctly assume that this result means that light travels slower in optical fibre than through air. The conclusion drawn from this experiment is that the speed of light traveling in glass

is inferior to the speed of light traveling in vacuum, in this particular case the air.

Let us now see a similar case, only the optical fibre is now replaced by a different optical medium behaving as a tunnel barrier, as we can see in Fig.1.4.

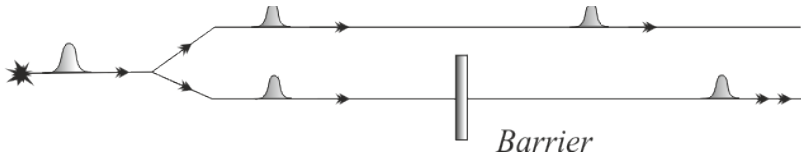


Figure 1.4: The light pulse which crosses the tunneling barrier arrives before the one traveling through air.

The result of this experiment, against what might be expected, is that the pulse following the path below, where the tunnel barrier is located, arrives before the pulse traveling though the air. As stated, all the experiments of this kind, and there have been many done all throughout the world, have always provided the same result. The pulse following the tunnel barrier arrives before the one traveling through the air.

If we applied reasoning similar to the first case where the medium was an optical fibre, the conclusion would be obvious and it would indicate that light had travelled faster in the tunnel barrier than through air. Meaning that inside the tunnel barrier we would have a superluminal velocity.

However and here is where the problem is, since this conclusion is contrary to one of the postulates of the theory of relativity which claims that the maximum possible velocity is c, that is, the velocity that light reaches in vacuum.

Many authors, as we have already pointed out, have tried to demonstrate that the results of these quantum experiments are not in contradiction with the theory of relativity.

It is amazing to see these people by one side claiming that relativity, a causal theory, is quite correct by the other side stating also that orthodox quantum mechanics, an inherently non causal theory where time and space are not relevant, is also correct. How is it possible to understand this conceptual and logical contradiction!

1.4 Fundamentals of Hyperphysics

Recently a new more general complex physics, the Hyperphysics, was developed in its essentials [4]. The basic idea is that the physical systems are in permanent reciprocal interaction modifying therefore the interacting medium and being modified at the same time. On the other hand we are always dealing with a finite physics. In this sense it is not possible to derive universal physical laws, that is, universal rules and their consequent universal constants. The best we are allowed to do is to propose finite expressions that could approximately describe the complex interacting natural phenomena. Still if the interacting conditions or the level of description, change, these expressions and naturally the constants linking the variables, traducing the phenomena, may also change. Hopefully we may, and always with great care, in certain broad general conditions enunciate general principles such as the principle of eurhythmy. Still we need always to be very careful. We must bear in mind that, as the human knowledge increases the domain of this new complex and finite physics also enlarges. Theories are no more than human constructions, resulting mainly from the information we are able to gather, depending significantly on our mental and experimental tools so, do not stand for final definite and eternal laws. The best we may hope is to have an increasingly better and better description of Reality.

This new global and nonlinear physics which still keep using the conceptual tools of space and chronological time is built upon the following assumptions:

1. First assumption:
There is an objective Reality. This reality is observer-independent, yet, it is understood that the observer interacts with the very same reality being able to change it and of course of being changed in a greater or lesser degree.

2. Second assumption:
There is a basic physical natural indefinite medium named the subquantum medium. All physical processes occur in this natural indefinite medium.

3. Third assumption:
What are called physical entities that is, the particles, fields and so on, are more or less stable finite organizations of the basic indefinite subquantum medium.

4. Fourth assumption:
In general the complex particles, stable organizations of the subquantum medium, are composed of an extended region, the so called theta wave, and inside it there is a kind of a very small localized structure, the acron.

5. Fifth assumption:
The principle of eurhythmy. This organizing principle states that the acron inside

the theta wave field follows a stochastic path that in average leads it to the regions were the intensity of the theta wave field is greater.

The first assumption of essentially philosophical nature stands for the realistic belief that there is something out of which our ideas and science derive. Science is no more than an attempt to describe the way we interact and understand the same very reality.

The second basic fundamental statement assumes that there is a natural physical medium of indefinite or chaotic nature, the subquantum medium. By chaotic medium we understand an indefinite medium where, in general, we cannot make causal relationships. Still, in this subquantum medium there can be more or less stable organized regions. These finite stable organized regions, states of the subquantum medium, are precisely where we can establish comprehensible relationships. What we call physics is no more than the description, at the different scales of observation, of the reciprocal interactions among these finite more or less stable organizations of the subquantum medium. So, in this sense, time that is, chronological time and consequently space are not here seen as primary basic concepts, but only as convenient helpful tools helping us to establish an intelligible relationship among the diverse interacting organized regions of the subquantum medium.

The concept of subquantum medium was introduced early in the first quarter of the XXth by the great French physicist Louis de Broglie [11] to describe quantum phenomena, namely the duality wave-corpuscle. Here this natural basic concept is generalized from the strict domain of quantum physics to include all physics.

The third assumption characterizes the nature of the physical entities, commonly known as particles, fields and so that here are seen as very complex entities. In this approach to describe reality it is assumed that the natural phenomena, at the different scales of observation, is no more than a reflex of the evolution and interaction of these finite stable organizations of the subquantum medium. So, in this sense, the aim of physics is to look for a description of the behavior of these organized structures and of their reciprocal mutual interactions.

The fourth assumption concretely specifies the nature of the complex physical particle. Also in this case the initial proposal for the nature of the complex particle was made by de Broglie [11] in quantum domain in order to explain the duality wave-corpuscle. Now this concept of de Broglie complex particle was generalized [12] from pure quantum physics to include all physics. In this assumption it is stated that the complex particles are compose of an extended part, the wave, and inside there is a well localized and in general indivisible, yet complex structure

relatively very small compared to its wave. The wave is named theta wave and the small localized structure the acron. Mathematically we could write

$$\phi = \phi(\theta, \xi) \tag{1.1}$$

or, assuming the simplest linear approach, as de Broglie did

$$\phi = \theta + \xi \tag{1.2}$$

where ξ stands for the acron and θ, naturally for the theta wave.

In previous works, following de Broglie, this very small high energetic region of the complex particle was called, singularity or even corpuscle. Still due to the confusion with the concept of mathematical singularity and from the fact that this region of the particle has an inner very complex structure it is now named by the Greek word acron13. This word comes from the Greek $\acute{\alpha}\kappa\rho o\nu$ meaning the higher pike like in acropolis, the higher city.

The following drawing, Fig.1.5, tries, roughly, to picture the real part of the complex particle.

Figure 1.1: Graphic sketch of a complex particle.

The fifth assumption corresponds to the laying down of the principle of eurhythmy as the cornerstone, as the very organizing principle for helping in the description

of the natural phenomena. The principle of eurhythmy concretely states that the acron possesses a kind of sensorium, its theta wave, with which it feels the surrounding medium. The acron being immersed in its theta wave moves in a stochastic way preferentially to where the intensity of the theta wave field is greater. This is a natural consequence of that fact that if the acron moves to other regions of lesser intensity is mean life is unsurprisingly shorter. This principle has been generalized by some authors [14] to include other sciences like for instance biology and others.

As may be easily understood the principle of eurhythmy is only meaningful in the context of complex systems. Even in the limit case of the fundamental acron the situation keeps the same because this minute entity is indeed already a very complex organized structure of the subquantum medium. The principle tells us that acron transits from one state of the theta wave field to other not in a deterministic way. This means that it is not possible to predict neither from the basic theory nor due to the multiple highly complex interactions with the medium the future state of the acron. This impossibility of predicting, even in principle, the future state of the acron is described through a chaotic interaction between the acron and the theta wave field which limits our predicting capability. Still it must be understood that it does not stand for an ontological truth but only for a mere operational pragmatic statement. Furthermore, in order to better clarify the starting basic assumptions, it is convenient to keep in mind that here the concept of chaos refers to an epistemological chaos and not an ontological chaos. In any way, this basic principle tries to describe the very complex reciprocal interactions so that, even in principle, it is not possible, at least at this stage of description of the physical reality, to predict with certainty the next outcome. Even if there is an inherently practical impossibility of predicting the next state of the acron it is nevertheless possible to establish an overall statistical tendency for the propensity for the acron to reach the next stage. This fact leads naturally to the practical formulation of the principle of eurhythmy that has the great advantage of allowing an easy mathematical formulation. Thus, in this sense and under the acknowledged approximations, the principle of eurhythmy states that the acron transits from a previous state to the next state in such a way that the transition probability is proportional the intensity of the theta wave field.

On the other hand it is also convenient to keep in mind that due to the highly complex nonlinear nature of the phenomena from one scale of observation and description of the Physics to the next it happens that the new emergent complex entities, even if they are a composition of parts, nonetheless their properties cannot, in general, be derived from the properties of the building parts. This statement is a simple consequence of the fact that the composite parts interact and therefore

modify themselves reciprocally in a greater or lesser degree, so that the whole, the resulting emergent entity has properties of its own. The best we may aim is to predict in certain particular given conditions the emergence of a new physical entity and, if we are fortunate enough, some of their general broad properties.

1.4.1 The Master Equation

From the basic principles of Hyperphysics it is possible to derive following a heuristic process the fundamental master nonlinear equation, which reads:

$$-\frac{\hbar^2}{2\eta}\theta_{xx}+\frac{\hbar^2}{2\eta}\frac{|\theta|_{xx}}{|\theta|}\theta+U\theta=i\hbar\theta_t \tag{1.3}$$

In order to obtain some simple particular solutions to the nonlinear master equation it will be more useful to start from the equation split into two balance equations: the Hamilton-Jacobi and the continuity equations,

$$\begin{aligned}\frac{1}{2\eta}\varphi_x^2+V&=-\varphi_t\\ \frac{1}{\eta}\partial_x(a^2\varphi_x)&=-\partial_t a^2\end{aligned} \tag{1.4}$$

or more simply

$$\begin{aligned}\frac{1}{2\eta}\varphi_x^2+V&=-\varphi_t\\ \frac{1}{\eta}(2a_x\phi_x+a\varphi_{xx})&=-a_t\end{aligned} \tag{1.5}$$

A possible simple family of solutions may be obtained assuming a linear form for the phase of the type

$$\varphi=px-Et-\delta \tag{1.6}$$

with

$$\varphi_x=p;\ \ \varphi_{xx}=0;\ \ \varphi_t=-E \tag{1.7}$$

we see that indeed is solution of the first equation with

$$p=\sqrt{2\eta(E-V)} \tag{1.8}$$

For this particular value of the phase the second equation converts into

$$\frac{p}{\eta}a_x + a_t = 0 \tag{1.9}$$

or,

$$\frac{\partial a}{\partial x} + \frac{1}{v}\frac{\partial a}{\partial t} = 0 \tag{1.10}$$

which, as can be seen, is a linear equation. This result is very interesting by itself because if one restricts oneself to that particular linear form for the phase, then the composition rule for the solutions becomes additive for the amplitude and consequently the superposition principle is recovered in this particular case.

The general solution to the linear equation for the amplitude can be written in the form

$$a = a(x - vt - l) \tag{1.11}$$

Then, for this particular case of a linear phase the general solution to the nonlinear master equation is given by

$$\theta = a(x - vt - l)e^{\frac{i}{\hbar}(px - Et - \epsilon)} \tag{1.12}$$

1.4.2 Solutions to the Master Equation in a rectangular potential

In this section we are going to study some simple solutions to the nonlinear master equation in a square potential. Naturally we are well aware that it represents only a rough approximation to the real physical situation. What we call classical potential is nothing more than a useful operational description of the interacting behavior of an extended real theta wave field with the entering complex particle. This theta wave field as we know results from the composition of many individual theta waves that are in permanent reciprocal interaction, so it describes only the average behavior of it. In this simplistic approach this potential is assumed to be constant having a vertical abrupt variation in the very sharp boundaries. Hardly any real extended physical field behaves like this. Yet this coarse simplification allows us to do the calculations without approximations and therefore have a glimpse of the real physical situation. In the same feet stands Kepler law claiming that the orbits of the planets are ellipses. Everybody knows that this corresponds to a very simplistic and highly idealized situation because no real planet follows in reality a perfect elliptic motion. Still this idealized approximation has proven very useful because it has allowed us, with the addition of the so-called due corrections, to predict under reasonable margin of error the position of the celestial bodies. In our

case we know that the equations we may use, namely the fundamental nonlinear master equation, constitutes only an approximate description of a very complex reality and furthermore the found solutions may be adequate only under certain very particular constrains and approximations. Yet, even with its fragilities and weaknesses, it is the best method we have since the beginning of the scientific revolution.

The graphical representation of this abstract highly idealized square potential, with the indication of the time evolution is seen in Fig.1.6.

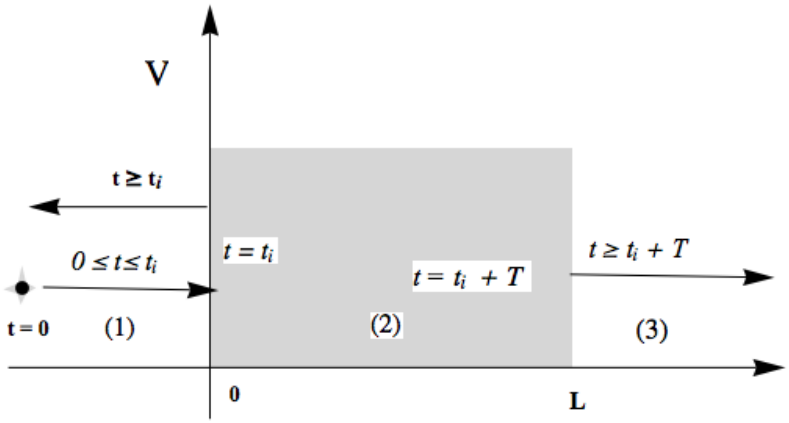


Figure 1.2: Square barrier

Since in this case the potential is constant by regions for each one we may write, as we have seen, for the phase

$$\varphi = (kx - \omega t + \delta) \tag{1.13}$$

and for the amplitude the generic form

$$a = a(x - vt - l) \tag{1.14}$$

with

$$k = \frac{1}{\hbar}\sqrt{2\eta(E-V)}, \quad v = \frac{1}{\eta}\sqrt{2\eta(E-V)}. \tag{1.15}$$

In this situation a generic form for the theta wave, under the stated conditions, may be written

$$\theta(x,t) = Ae^{-\frac{(x-vt-l)^2}{2\sigma^2}+i(kx-\omega t-\delta)} \tag{1.16}$$

Naturally, when $V > E$, we are in the tunneling situation. Classically speaking the incident particle would be totally reflected, yet both theory and experiments show that this statement is wrong. Even in these circumstances when the energy of the incident particle is less that the energy of the barrier the particle indeed may cross the barrier.

De-emergence and emergence of a complex structure

In tunneling conditions we have $V > E$, implying that the concrete action of the tunnel may be described mathematically by transforming from real to imaginary the velocity and the spatial frequency of the incident wave in such way that inside the barrier, where $V > E$ we have

$$k_t = i\frac{1}{\hbar}\sqrt{2\eta(V-E)} = ik_2, \quad v_t = i\frac{1}{\eta}\sqrt{2\eta(V-E)} = iv_2 \tag{1.17}$$

with

$$k_2 = \frac{1}{\hbar}\sqrt{2\eta(V-E)}, \quad v_2 = \frac{1}{\eta}\sqrt{2\eta(V-E)} \tag{1.18}$$

From these relations one concludes that the tunneling action on to the incident wave may be described by a kind of mathematical tunneling operator which transforms the spatial frequency and the velocity from real to imaginary

$$k \overset{Tunneling}{\longrightarrow} k_t = ik'$$
$$v \overset{Tunneling}{\longrightarrow} v_t = iv'$$

Naturally the inverse operation that is, the passage from a tunneling region to a normal one is also possible and follows the same rules conducing again to a real velocity and spatial frequency.

In these conditions the solution to the nonlinear master equation for the case of a linear phase implying a constant potential may be written inside the barrier

$$\theta(x,t) \overset{Tunneling}{\longrightarrow} \theta_t(x,t) = Ce^{-\frac{(x-iv_2t-l)^2}{2\sigma_2^2}+i(ik_2(x-l)-\omega_2 t+\delta)} \tag{1.19}$$

giving after development

$$\theta_t(x,t) = Ce^{\frac{(x-l)^2}{2\sigma_2^2}-k_2(x-l)}e^{\frac{v_2^2}{2\sigma_2^2}t^2}e^{i\left(\frac{x-l}{\sigma_2^2}v_2-\omega_2\right)t} \tag{1.20}$$

Looking at this meaningful mathematical expression one sees that it is composed of a localized Gaussian structure centered at point ?, a dumping term decreasing exponentially with the distance, a nonlinear phase modulating term, and an emergent element ?increasing exponentially with the square of the time. It is worth to call the attention to the importance of this term, which is very interesting because it describes the emergence of a localized structure out of the very feeble theta wave field, of practically no relative intensity. This phenomenon is in a way very similar to the emergence of water soliton in which a very strongly localized non dispersive wave seems to emerge as if out of nothing in certain given conditions. The plot of this function for arbitrary values of the parameters is shown in Fig.1.7, for the theta wave function a) and for the amplitude b)

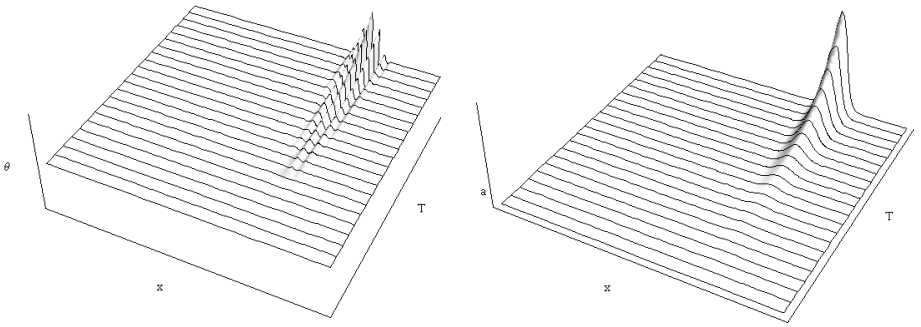


Figure 1.3: Plot for the theta wave a) and for the amplitude b) showing the emergence of a complex structure

The maximum of the amplitude is given by

$$\frac{\partial a_t}{\partial x} = 0 = -\left(\frac{x-l}{\sigma_2^2} + k_2\right) a_t \tag{1.21}$$

that is

$$l = x + k_2\sigma_2^2 \tag{1.22}$$

Now if one fixes the maximum of the amplitude at the end of the tunnel we have

$$l = L + k_2\sigma_2^2 \tag{1.23}$$

Since we are dealing with a nonlinear differential equation the solutions cannot in general be summed. Nevertheless in this particular case for the same concrete value

of the phase the amplitudes can be summed. Yet only on the regions where the value of the phase is the same as happens to be the case on the point $x = 0$.

In the case of zero value for the potential outside the barrier we may write, for the solutions in the diverse regions for the boundary conditions indicated in Fig.7.3,

$$\begin{cases} \theta_{1i}(x,t) = A\, e^{-\frac{\left(x-v_1(t_i-t)\right)^2}{2\sigma_1^2}+i(k_1x-\omega_1(t_i-t))}, & x \leq 0,\ 0 \leq t \leq t_i \\ \theta_{1r}(x,t) = B\, e^{-\frac{\left(x+v_1(t-t_i)\right)^2}{2\sigma_1^2}+i(-k_1x-\omega_1(t-t_i))}, & x \leq 0,\ t \geq t_i \\ \theta_t(x,t) = C\, e^{-\frac{(x-l)^2}{2\sigma_2^2}-k_2(x-l)} e^{\frac{v_2^2}{2\sigma_2^2}(t-t_i)^2} e^{i\left(\frac{x-l}{\sigma_2^2}v_2-\omega_2\right)(t-t_i)}, & 0 \leq x \leq L,\ t_i \leq t \leq t_i+T \\ \theta_3(x,t) = F\, e^{-\frac{\left((x-l)-v_1(t-(t_i+T))\right)^2}{2\sigma_1^2}+i(k_1(x-L)-\omega_1(t-(t_i+T)))}, & x \geq L,\ t \geq t_i+T \end{cases} \tag{1.24}$$

The value of the constants are fixed by the boundary conditions

$$\begin{cases} \theta_{1i}(0,t) + \theta_{1r}(0,t_i) = \theta_t(0,t_i), \\ \theta'_{1i}(0,t) + \theta'_{1r}(0,t_i) = \theta'_t(0,t_i) \end{cases} \tag{1.25}$$

$$\begin{cases} \theta_t(L,t_i+T) = \theta_3(L,t_i+T), \\ \theta'_t(L,t_i+T) = \theta'_3(L,t_i+T) \end{cases} \tag{1.26}$$

with, as expected, $l = L + k_2\sigma_2^2$.

The derivatives give

$$\begin{cases} \theta'_{1i} = -\left[\frac{x-v_1(t_i-t)}{\sigma_1^2} - ik_1\right]\theta_{1i} \\ \theta'_{1r} = -\left[\frac{x+v_1(t-t_i)}{\sigma_2^2} + ik_1\right]\theta_{1r} \\ \theta'_t = -\left[\frac{x-l}{\sigma_1^2} + k_2 - i\frac{v_2}{\sigma_2^2}(t-t_i)\right]\theta_t \\ \theta'_3 = -\left[\frac{(x-L)-v_1(t-(t_i+T))}{\sigma_1^2} - ik_1\right]\theta_3 \end{cases} \tag{1.27}$$

For the first boundary we have

$$\begin{cases} A + B = C\, e^{-\frac{l^2}{2\sigma_2^2}+k_2l} \\ ik_1A - ik_1B = \left(\frac{l}{\sigma_2^2} - k_2\right) C\, e^{-\frac{l^2}{2\sigma_2^2}+k_2l} \end{cases}, \tag{1.28}$$

from which we get

$$B = \frac{1 + \frac{i}{k_1}\left(\frac{l}{\sigma_2^2} - k_2\right)}{1 - \frac{i}{k_1}\left(\frac{l}{\sigma_2^2} - k_2\right)} A, \tag{1.29}$$

and

$$C = 2\left[1 - \frac{i}{k_1}\left(\frac{l}{\sigma_2^2} - k_2\right)\right]^{-1} e^{\frac{l^2}{2\sigma_2^2} - k_2 l} A \tag{1.30}$$

For the second boundary conditions we have

$$\begin{cases} \theta_t(L, t_i + T) = C\, e^{\frac{1}{2}k_2^2\sigma_2^2} e^{\frac{v_2^2}{2\sigma_2^2}T^2} e^{i(k_2 v_2 - \omega_2)T} \\ \theta_t'(L, t_i + T) = \left(i\frac{v_2}{\sigma_2^2}T\right)\theta_t(L, t_i + T) \end{cases} \tag{1.31}$$

and

$$\begin{cases} \theta_3(L, t_i + T) = F \\ \theta_3'(L, t_i + T) = ik_1\theta_3(L, t_i + T) \end{cases} \tag{1.32}$$

So, in order to secure the continuity we have

$$F = C\, e^{\frac{1}{2}k_2^2\sigma_2^2} e^{\frac{v_2^2}{2\sigma_2^2}T^2} e^{i(k_2 v_2 - \omega_2)T} \tag{1.33}$$

Or, expressing F in terms of A

$$F = 2e^{\frac{1}{2}k_2^2\sigma_2^2} e^{\frac{v_2^2}{2\sigma_2^2}T^2} e^{i(k_2 v_2 - \omega_2)T}\left[1 - \frac{i}{k_1}\left(\frac{l}{\sigma_2^2} - k_2\right)\right]^{-1} e^{\frac{l^2}{2\sigma_2^2}} A \tag{1.34}$$

Emergence time

From the last boundary condition it is possible to determine the value of the emergence time T

$$\theta_t'(L, t_i + T) = \theta_3'(L, t_i + T) \Longrightarrow \left(i\frac{v_2}{\sigma_2^2} T \right) \theta_t(L, t_i + T) = ik_1 \theta_3(L, t_i + T), \quad (1.35)$$

from which we get

$$i\frac{v_2}{\sigma_2^2} T = ik_1, \quad (1.36)$$

that is

$$T = \frac{k_1}{v_2}\sigma_2^2, \quad (1.37)$$

recalling that

$$k_1 = \frac{1}{\hbar}\sqrt{2\eta E}, \quad v_2 = \frac{1}{\eta}\sqrt{2\eta(V - E)}, \quad (1.38)$$

we have finally

$$T = \frac{\eta}{\hbar}\sqrt{\frac{E}{V - E}}\, \sigma_2^2 \quad (1.39)$$

This expression tells us that the emergence time, as expected, does not depend on the length L of the tunneling barrier. Furthermore, for each tunneling barrier, a kind of emergence velocity may be derived from it

$$v_{emerg} = \frac{L}{T} = \frac{\eta}{\hbar}\sqrt{\frac{V - E}{E}}\, \frac{L}{\sigma_2^2}. \quad (1.40)$$

Since in this expression, for a given particle and barrier eight, the time T is constant it follows that for a very large L, that is $L \gg T$, the emergence velocity approaches infinity. This implies that, in this situation, we are before what is commonly called zero time transition.

Still we must be aware that this does not represent a true velocity since the habitual concept of velocity does not apply inside the tunneling barrier. This velocity corresponds to a kind of velocity of emergency, a velocity in time, the rate of variation in time, of a structure outside the tunneling barrier. This emergent exit structure is much alike the initial one impinging at the beginning of the barrier.

Thus we have seen that upon impinging on to the barrier, the physical structure, mathematically described by a gaussian, disappears, that is de-emerges and then may reappear, emerge at a given region. By choosing the right conditions we may have an almost zero time transmission for the physical entity.

These results lead us directly to the magnum problem of understanding the concept of emergence and de-emergence That is how a certain complex physical entity starts existing as such as if out of nothing and then, on the contrary, under other conditions seems to disappear.

Since our basic archetype are the waves, organized perturbations of the subquantum medium, this process of emergence or de-emergence may be easily understood in their basic lines. A certain group of waves upon interaction in a coherent way may give rise to a complex structure, a complex global wave, relatively stable. That is, at the scale of observation and description the said structure maintains its general characteristics. Naturally this complex emergent structure resulting from the composition of other more elementary waves has, in line of principle, properties that could not be inferred from the properties of the constituent elementary waves since we are dealing not with a simple Cartesian linear superposition. In the case of de-emergence it happens that the previously waves which were in a state of overall coherence begin, due to the reciprocal interaction with the medium, to lose coherence and the complex structure starts disorganizing till it disappears completely leaving no apparent footprint. Still it may happen that in certain particular conditions some kind of kernel, some residual basic properties, remains even if, at the scale of observation, it seems that the complex structure has completely vanished. On the other hand the emergent entities could only be formed if the reciprocal interacting conditions of the elementary waves with themselves and with the medium are such that the resultant emergent being follows the principle of eurhythmy. This means that the new state, the emergent entity, offers better global persisting condition for the basic constituent elements.

1.5 Teleportation

Teleportation is a subject very dear to most science fiction writers and readers. In it there generally exists a kind of portal one enters. After making the right connections one founds oneself somewhere kilometers or thousands of thousands of kilometers away from the initial point. That is everything happens as if we travelled at an infinite velocity since the transition time is about null.

1.5.1 Quantum Mechanics

Since the nineties some physicist working in the foundations of quantum mechanics15 have developed some proposals of experiments connected with a very special type of quantum mechanical interaction they coined quantum teleportation. Some of these experiments have already been made. What is called quantum mechanical teleportation is related with the so-called quantum entangled or quantum correlated states. Since orthodox quantum mechanics is a non-local and non-temporal theory there no in principle difficulty in accomplishing what is called teleportation. In any case the experiments proposed and made are concerned with the instantaneous "transmission" of a quantum correlate or entangled states. Still, since the name is somewhat misleading, some not well informed people, which are the great majority, may be lead to believe that they are before the deed announced in science fiction books which is not the case.

1.5.2 Relativity

Even in relativity there is something somehow akin to teleportation [16]. According to certain authors this feat can be accomplished either by the modification of the fabric of the space-time or by the technique of wormholes resulting from blackholes. In the first case what they call fabric of the space-time is modified in such a way that two initially very faraway physical entities may be placed in conditions that in the limit the distance between them disappears, conducing in these circumstances to a zero transit time from one point to the other. In the second case with the help of what they name gravitic singularity, the blackhole, it would be possible, according to them, to produce a wormhole allowing also a zero time transit time.

Needless to say that it is very hard to tell the difference between these theoretical conclusions and pure science fiction. It is usually told, science diffusion makes a big noise about it, that the said conclusions come out naturally from general relativity. In reality this is not entirely true because these conclusions result mainly from the utterly ad hoc assumption introduced during the calculations and not from the theory itself.

1.6 Physics of the becoming – The physics beyond space and chronological time

Now that we have presented some relevant information concerning the state of the art in what deals with the concepts of time and space we would like to clarify the distinction we made at the beginning of this work between the concept of time understood as the becoming and the chronological time.

Chronological time that is, the time of the clocks, is something, a measurement that we make with the help of space. Without space chronological time would be totally meaningless. A clock, an apparatus for measuring the chronological time, could be from a simple rod placed vertically on the earth to a very sophisticated device. In the simplest case by localizing the position of the shadow of the rod we may be able to tell the chronological time. In this simple case the time measurement results, in last instance, from spatial measurements that is, the position of the shadow. This conclusion, valid for one of the simplest clocks, is also valid for any other time measurement device no matter how complex it may be. So, in this sense time, that is chronological time and space are intimately connected. It is precisely because of this intimate connection that relativity developed the concept of space-time, a linear relationship between space and time. This space time connection is understood as an improvement to the absolute space and time of Newton.

Time in the sense of becoming, that is the True Time, is entirely another matter. Time in this deep sense of becoming is related with the change, the alteration, the modification, which, in line of principle, is beyond space. Is something basic inherent to the change, the alteration of a given state. More than that, since the very definition of state implies this ever changing.

From the presented evidence it is reasonable to infer that there is fair experimental and conceptual support indicating that the concepts of space and chronological time are indeed not basic concepts but mere useful tools more or less adequate according to the scale of interaction and observation and description of reality. Still, as pointed out in the introduction, we must be full aware that since all our evolution till today was done precisely using mostly these tools it shall prove very hard to pass without them. Indeed, it is not ease to abdicate from utilization of the traditional concepts of space and chronological time.

All our words, whole our language is deeply rooted in our long-established traditional ways of thinking. So, we have to do the best we can, yet fully aware that there shall necessarily be, here and there, some less clear and eventually less correct propositions and even some contradictions. Still we know that in order to develop a better global language containing as a particular case the traditional

linear Cartesian approach rooted on the concept of space and chronological time shall need very hard work and will take some time.

1.6.1 Taking teleportation to its ontological consequences

To begin with we must say that even the very word teleportation is misleading since it contains deeply in it the concept of space. Indeed the word teleportation is the composition of tele + portation. Tele means distance that is, space. Portation stands for carrying something from one place to another, again the concept of space implicit. A better word for describing what really happens would be **zero time transition** from one state to another. Meaning in this case the change of a given state to another different state occurs in zero time.

Even if experimental evidence suggests that at the quantum scale, by means of tunneling, teleportation is possible nonetheless we have no experimental proof, at least as far as we are able to discern, that teleportation is possible at other scales of description of Reality. Even so we shall try to derive the logical consequences and physical implications of zero time transition assuming, naturally, that it is possible, in line of principle, at the diverse scales of description of Reality.

As we have already called the attention we are full immersed in the concept of space. Our mathematics, our physics, all our science were built upon this very concept. Yet, and here is the amazing point, somehow this apparently sound construction shows some holes, some weaknesses either from the conceptual point of view and from the experimental evidence. From the conceptual point of view, we have the teleportation, or zero time transition, that has been developed at least as a possible conceptualization. These facts in themselves are not new. In almost every major religion one of the attributes of God is precisely the omnipresence. This attribute means that the Super Entity, that is, God is beyond space and time. So, at least for this Super Being space and time are not basic categories. On the other hand many rites either from the religions of the Book or from others present the ideal of Unity meaning a true the absence of space. Even a paradigmatic theory like orthodox quantum mechanics, one of the best physical theories ever built by man, denies traditional causality. In this theory space and chronological time play no effective role. Naturally we know that the price to pay for was the rejection of causality that is, the denial of the primacy of space and time led the denial of the objective reality. By getting get rid of space and chronological time orthodox quantum mechanics lead to the possibility for the homo quanticus to acquire the gift of omnipresence till then only appanage of God or of other Super Entities. Naturally the cost to pay for this possibility was, as we have mentioned, the denial of the objective reality. Reality in this theory is a making of the observer. More

precisely, it is the consciousness of the observer that out of a bunch of potentialities, of a cluster of probabilities "chooses" the one to be actualized or realized.

1.7 Physics of Becoming – physics beyond space and chronological time

The general Physics of Becoming is a causal theory. In order to better understand this statement it is opportune to clarify here the meaning of the word causal. Being that the concept of causality is opposed to the concept of creation. Creation understood in the sense that something comes out of nothing. This appearance occurs as a kind of miracle that is, in an explainable and incomprehensible mysterious way. These miracles, these unexplainable things, take place by the will of God, or Gods or even, as it happens in orthodox quantum mechanics, by the act of measurement made by the observer or, more precisely the observer consciousness. Causality means that there are no miracles; there is always, at least in principle, an explanation for a certain happening. Even if at a certain given human state of development we are not able to understand the why of a certain phenomena, we nevertheless believe that future advances in science, in the knowledge will allow us to understand it. In last instance nothing happens out of nothing even if we are not able to devise the explanation for the actual happening. Nevertheless, and here is the point we want to stress, causality, traditional causality, understood in the most common sense assumes that this actual emergent something is the result of many correlated happenings that take successively place in time and space. That is, an actual event is something which resulted from a more or less long sequential process that has occurred in space and time. Now, in this more general framework of the Physics of Becoming, causality has a much more general meaning. Indeed it means that there is a continuous becoming in which each emergent state, each being, each physical entity, is the natural outcome of a complex reciprocal interaction process among the diverse states. So, in this more general meaning causality is something beyond space and chronological time. Now it is opportune to show that Hyperphysics may be understood that is, may be integrated in the more general framework of the Physics of Becoming.

We know that in Hyperphysics the basic concepts are: the subquantum medium, the concept of wave and acron plus the principle of eurhythmy. Since we assume that the Physics of Becoming plays the primary role in allowing us in the understanding of Reality it is not only conceptually convenient but also necessary to derive Hyperphysics, as a particular case of this more basic physics. Indeed it is essential to understand in this much more general and basic framework, the

true meaning of the fundamental concepts of Hyperphysics. By its turn, since as was already shown4 Hyperphysis contains that is, integrates formally traditional physics this would show that the Physics of Becoming is indeed a global integrating theory. So this Physics of Becoming in any way denies or is against the truly great achievements of traditional physics. On the contrary, these great achievements of human reasoning shall be now perfectly understood and integrated in a more vast and global scientific framework.

The concept of subquantum medium poses no problems. The subquantum medium, the Apeiron, existing independently of the scale and of the observer, is the indefinite or most basic entity which exists by itself independently of the auxiliary subsidiary concepts of space and time. The subquantum medium is the primary the very basic entity which exists by itself. That is, the subquantum medium or the Apeiron is the True, the Real Being, the one which is by itself.

The concept of theta wave seems at first more difficult to understand without the supporting concept of space. Still, if we look carefully we may see that, in our fundamental and in general indefinite subquantum medium the wave constitutes precisely a particular state of it, one among a large multiplicity other possible states. These states, these waves are particular concrete situations of medium where the becoming happens. Moreover, this becoming has the fundamental property of being, in line of principle, predictable. So, our science, in its very essence, consists in the predicting of the becoming of a given physical state out from the interaction with the other possible different states. It is precisely the concept of physical real wave, an organized, that is predicable difference of the subquantum medium, the theta wave, which constitutes the fundamental underlying state, in permanent becoming allowing the prediction of the future states. In this sense, being a state, being a wave, implies an organized entity which, in line of principle, is susceptible of prediction. Each state is in permanent becoming that is, this entity is the subject of the change. The wave is primary characterized by the frequency which stands for the repetition of given, more or less complex temporal, pattern in the continuous becoming. So, now the concept of frequency is mainly connected with the changing from one state to another. That is, the rate of becoming of similar states leads then to the concept of frequency. A being, an organized state is nothing more than a state from which we are, in principle, able to make predictions. In the raw subquantum medium we are not able to make predictions because by its very nature the basic primordial Being is indefinite. On the other hand, interaction, or reciprocal interaction of states is also a very important concept useful to help in describing the change from a particular initial state to another state. The number of possible end states of a reciprocal interaction process are, in line of principle, many. So, the word interaction stands, in the Physics of the Becoming,

for the concept for describing, for connecting the propensities17 for the transition, for the becoming of one particular state out of other possible previous states.

Still we must be aware that these theta waves, organized states of the subquantum medium, are not, in general, directly observed at the given scale of interaction and observation. What we do actually observe is the acron. The acron is the organized entity that emerges out of the composite global theta wave resultant from the mutual reciprocal interaction among the diverse theta waves. From this coherent interaction of states emerges a kind of unitary entity, the acron. That is, the acron is a kind of very special highly organized observable state which emerges out from the previous states. It all happens as if out of nothing, from the basic states, the acron emerges becoming a real entity that may then be observable. Naturally if the acron emerges it may also de-emerge, disappear, into the unobservable more basic sates, the theta waves.

In order to better understand this important point it may prove convenient to use a metaphorical example of a large multitude o people talking to each other by pairs, for instance. Since each pair of persons is talking quite independently of each other the sound waves produced by them are completely uncorrelated. In this situation the overall wave resulting from the composition of all these incoherent sounds produces a very big random noise out of which nothing could be understood. Now suppose that an igniting sound like for instance the beginning of a hymn beloved by everyone is produced by someone. Then everybody starts progressively singing the dearly loved hymn. In such conditions it occurs that all single sound waves produced by each single person start beginning in phase coherence and so that a giant overall coherent sound wave is produced that is, emerges as if out of nothing. So, out of the chaotic random wave emerges a giant powerful coherent sound wave that later may naturally de-emerge into nothing, the random noise.

It is opportune here to call the attention to the fact that the basic concept of theta wave, understood as a state, is very general and keeps its meaning valid at any scale of interaction and observation. This means that the nature and state of complexity of the organized constituent elements may, generally, vary according to the scale. On the same foot stands the concept of acron. At a certain scale the acron may be the essential observed entity. Yet, at another more basic scale, where for instance the acron is the whole reality we are dealing with, it may then be understood as a wave.

From what was seen it is possible to gather that there is a deep analogy between the previous studied tunneling effect and the basic processes of the Physics of Becoming. So, as far as we know, the tunneling effect was the first concrete scientific indication showing that indeed it is possible to develop a more rich and

global physics where the auxiliary concepts of space and chronological time are no longer important. In a way of speaking it is possible and even more it may be convenient to say that the observable physics is nothing more than a particular case that is, a manifestation of the tunneling effect, the de-emergence and the emergence of a being as if out of nothing. Indeed, as we have described in Hyperphysics, that is, with the help of the auxiliary concepts of space and chronological time, the acron upon penetrating the barrier de-emerges and then emerges, re-emerges in zero transition time without paying any attention to the so-called classical size of the tunneling barrier. In this sense, the tunneling effect from a mere laboratory physical curiosity becomes the very basis for a better understanding of the Physis, of Nature.

It is remarkable to find out that even if all our theories, our language, our words were so fully impregnate and even more so addicted on the concepts of space and chronological time yet something out of it emerges. Something emerges, something leaks out of this blocking conceptual spatial shield. This something opens our eyes showing to the evidence, that indeed space is not a basic concept. This something is precisely the tunneling effect a clear indication that these traditional concepts of space and chronological time, supposed to be basic and indispensable, play actuality only a secondary minor role. Indeed, they are only auxiliary concepts that in certain particular circumstances and under some approximations may prove adequate in helping us to understand and deal with some perceptible aspects reality. Still if we want to go further, to go out of the box, out of this prison it is indispensable develop a whole science of the Becoming.

The transformation, the becoming of the diverse states into other more organized states does not, as it may be expected, follow an entirely chaotic unpredictable process. In reality these possible different states resulting from the becoming of one initial state in order to persist, in order to be observable must change in such a way as to follow, in average, the organizing principle of eurhythmy. This basic principle states that the becoming, the transformations which a state underwent are such that they tend, in average, to maximize the persistence of such state. Chaotic interactions if not according to the principle of eurhythmy lead the physical state to de-emerge, thus to the disappearance of it as physical organized state. The principle of eurhythmy is thus the basic organizational principle to allow us to make predictions.

So, to summarize it is opportune to clarify some important facts: In the physics beyond space and chronological time, the Physics of the Becoming, obviously, there is no inside and outside. These traditional concepts are now replaced by the much more general and meaningful concepts of similar and diverse that is, of particular sates of reciprocal interrelation. We, no more have to say that a certain state is

inside the other state or even outside the other state. This in reality means that a certain state is diverse from the other and shares with it some particular type of different interaction.

On the other hand, also in the Physics of Becoming the traditional basic concept: I am, in the sense of being here, of staying, in latin ego sto, is changed by the more fundamental concept I am, with the meaning of I exist, in latin ego sum, but now without any reference regarding space. So, we have to say: I do not stay, I exist. I exist, that's all! The very existence by itself implies the becoming which results from very complex reciprocal interacting relationship with the other beings.

1.8 Formalization of the Physics of the becoming

In this section we shall present a first attempt for putting into formal mathematical language the Physics of becoming. Our aim is to develop a mathematical apparatus without the habitual concepts of space and chronological time.

We know that at a certain step of the becoming, that is, at a certain time τ a given state $S^{\tau}_{\xi_0}$ is interacting reciprocally with the other possible states in general many. Next picture tries to represent besides the reference state only five possible others states and their mutual reciprocal interactions

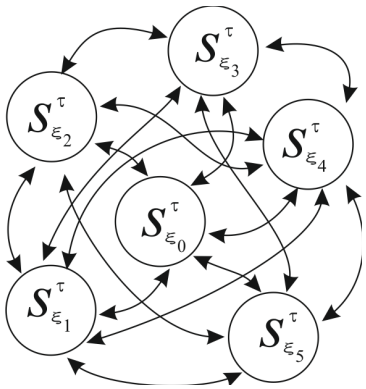


Figure 1.4: Reference state and five other states and their reciprocal interactions.

Let us then consider the same particular situation, represented in the sketch of only five possible states: $S^{\tau}_{\xi_1}$,$S^{\tau}_{\xi_2}$, $S^{\tau}_{\xi_3}$, $S^{\tau}_{\xi_4}$, $S^{\tau}_{\xi_5}$, plus the reference state $S^{\tau}_{\xi_0}$. Now, the next step of the becoming, in the next transition time $\tau+1$, the reference state

$S^{\tau}_{\xi_0}$ becomes the state $S^{\tau+1}_{\xi_0}$. This becoming, this transformation comes up from the mutual reciprocal interactions among the possible considered states. That is each state through their reciprocal interaction contributes to the becoming of the new state $S^{\tau+1}_{\xi_0}$. As shown in next sketch, below (Fig. 7.2).

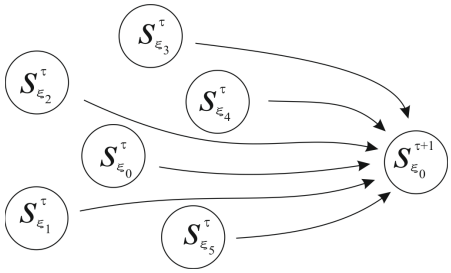


Figure 1.5: Transition of given state.

The reference state $S^{\tau}_{\xi_0}$ may transit to any of the possible available states

$$S^{\tau}_{\xi_0} \to S^{\tau+1}_{\xi_0} \to S^{\tau}_{\xi_i},\ i = 0, 1, 2, ..., n, ... \tag{1.41}$$

stochastically according to the greater propensity of each state. Assuming that the states are many and furthermore that in a first approach the linear rule may be applied without great deviation from what in a large average cases happens we may write

$$S^{\tau+1}_{\xi_0} = p^{\tau}_{\xi_0,\xi_0} S^{\tau}_{\xi_0} + p^{\tau}_{\xi_1,\xi_0} S^{\tau}_{\xi_1} + p^{\tau}_{\xi_2,\xi_0} S^{\tau}_{\xi_2} + p^{\tau}_{\xi_3,\xi_0} S^{\tau}_{\xi_3} + p^{\tau}_{\xi_4,\xi_0} S^{\tau}_{\xi_4} + p^{\tau}_{\xi_5,\xi_0} S^{\tau}_{\xi_5} \tag{1.42}$$

Here $p^{\tau}_{\xi_i,\xi_j}$ represents the propensity, that is the probability of transiting from state $S^{\tau}_{\xi_i}$ to state $S^{\tau+1}_{\xi_j}$. That is, the given initial state may remain the same $S^{\tau+1}_{\xi_0}$, or may become any one of the other possible states $S^{\tau+1}_{\xi_j}$, or a combination of states. Naturally, the final state is different in principle of the previous state, $S^{\tau}_{\xi_0} \neq S^{\tau+1}_{\xi_0}$ and generally we have $S^{\tau}_{\xi_0} \neq S^{\tau+1}_{\xi_j}$. As expected, the overall sum of the propensities or probabilities equals one

$$p^{\tau}_{\xi_0,\xi_0} + p^{\tau}_{\xi_1,\xi_0} + p^{\tau}_{\xi_2,\xi_0} + p^{\tau}_{\xi_3,\xi_0} + p^{\tau}_{\xi_4,\xi_0} + p^{\tau}_{\xi_5,\xi_0} = 1 \tag{1.43}$$

Expression (1.42) representing the becoming of a new state out of many possible states is nothing more than a particular mathematical expression of the principle of eurhythmy.

Naturally, the previous expressions may be generalized to any number of states giving the general equation of becoming

$$S_{\xi_0}^{\tau+1} = \sum_{i}^{n} p_{\xi_i,\xi_0}^{\tau} S_{\xi_i}^{\tau} \tag{1.44}$$

and the general probability, or propensity conservation equation

$$\sum_{i}^{n} p_{\xi_i,\xi_0}^{\tau} = 1. \tag{1.45}$$

In these conditions the continuum becoming of a state $S_{\xi_0}^{\tau}$ may be represented

$$S_{\xi}^{\tau} \to S_{\xi}^{\tau+1} \to S_{\xi}^{\tau+2} \to S_{\xi}^{\tau+3} \to S_{\xi}^{\tau+4} \to S_{\xi}^{\tau+5} \to ... \tag{1.46}$$

This state S, described by its characteristic lower index

$$\xi \equiv \xi_0, \text{or } \xi_1, \text{or } \xi_2, ...$$

underwent diverse transitions given by the upper index. Still even if from transition to transition the state changes, nevertheless somehow some of its basic identity remains. This something characterizing the state, the theta wave is here, at this stage, represented by the symbol ξ.

The state, the being S_ξ at a certain given stage of its becoming is properly characterized by its entire story

$$S \equiv S_{\xi}^{\tau,\tau+1,\tau+2,\tau+3,\tau+4,\tau+5,...} \tag{1.47}$$

The continuous becoming of a given state and the respective probabilities may be represented by

$$S_{\xi_0}^{0} \overset{p_{0,i}^{1}}{\to} S_{\xi_i}^{1} \overset{p_{0,i,i}^{2}}{\to} S_{\xi_i}^{2} \overset{p_{0,i,i,i}^{3}}{\to} S_{\xi_i}^{3} \overset{p_{0,i,i,i,i}^{4}}{\to} ... \tag{1.48}$$

in which the index i may assume the diverse possible values

$$i = 0 \vee i = 1 \vee i = 2 \vee i = 3 \vee ... \tag{1.49}$$

This means that the form of the propensities that is, the transition probabilities contain, in line of principle, the whole story of the process.

Since the number of possible states is, in principle very huge, in order to simplify the formalization and at the same time allow the making of calculations, let us consider a very simple situation of only three possible states. In this simple case the possible transitions are

$$S_0 \to S_0; \;\; S_0 \to S_1; \;\; S_0 \to S_2. \tag{1.50}$$

or more generally

$$S_i \to S_i; \;\; S_i \to S_{i-1}; \;\; S_i \to S_{i+1}. \tag{1.51}$$

On the other hand, even if in principle the transition probabilities contain the whole story of the process, we assume, in a first approximation, that they remain approximately constant, depending only of the two states

$$p^{\tau}_{\xi_i,\xi_j} \simeq p^{\tau+n}_{\xi_i,\xi_j} \simeq p_{i,j} \tag{1.52}$$

Furthermore, it is assumed in this linear approximation that the different states are independent, in the sense that they keep being approximately as such independently of the interactions with the other states. In this case, and under the stated approximations we are allowed to write the probability conservation equation

$$p_{i,i-1} + p_{i,i} + p_{i,i+1} = 1 \tag{1.53}$$

In these conditions the equation for describing the transition of the states may be written for the generic state

$$S_{i,\tau+1} = p_{i-1,i} S_{i-1,\tau} + p_{i,i} S_{i,\tau} + p_{i+1,i} S_{i+1,\tau} \tag{1.54}$$

where we have made

$$S^{\tau+1}_i = S_{i,\tau+1}. \tag{1.55}$$

It is convenient to remember that a single given state in general does not depend in general on one, two, three, or even four parameters. Indeed a state depends, in general, on a very large number of variables and parameters

$$S \equiv S(a, b, c, d, e, f, ..., N). \tag{1.56}$$

Only in very simple cases we may have $N = 1$, $N = 2$, $N = 3$, $N = 4$, in general $N \gg 4$.

In order to proceed with the actual calculations it is necessary define mathematically the form of the transition probabilities. We know that the principle of

eurhythmy tells us that the probability of a given state to change, to become another possible state follows according to the propensity of such state. Meaning that if a given physical being is in a certain state and if its transition to other state is more favorable to its very existence then this probability increases. Being that the actual value of the transition probability is greater the greater is favorability of such state. Inversely the transition probability decreases when the state is less favorable to the persistence of the initial state. This situation may be rendered by what is known as the intensity of a state, the organized subquantum medium that is, intensity of the theta wave. This intensity I_i is nothing more than a way of representing propensity for the transition of the sates.

In this situation we may define the transition probabilities for this simple case by

$$\begin{cases} q_i = p_{i,-1} = \frac{I_{i-1}}{I_{i-1}+I_i+I_{i+1}} \\ \\ \delta_i = p_{i,i} = \frac{I_{i-1}}{I_{i-1}+I_i+I_{i+1}} \\ \\ p_i = p_{i,i+1} = \frac{I_{i+1}}{I_{i-1}+I_i+I_{i+1}} \end{cases} \tag{1.57}$$

By the knowledge of I_i, or more generally $I_{a,b,c,d,e,f,\ldots,N}$, it is possible to evaluate the explicit form for the transition probabilities. Once knowing the form of the transition probabilities by substitution in the stochastic equation (7.9) we obtain the actual state after the transition. This implies that the generic state ?, where the square parenthesis means that the state depends implicitly on ?. This dependence is naturally much less direct.

The finite difference stochastic equation (1.54) assumes implicitly the adequacy of the additive rule. Nevertheless we know that in the physics of Becoming the infinite division, the infinite partition is not possible. In this case the minimum possible division corresponds to the difference between two possible states. Furthermore the stochastic equation describes only the statistical average behavior of a large ensemble of states considered as independent. The advantage of the process lies above all in its great simplicity, its weakness, in the fact that it represents a kind of compromise with the linear approach.

In this notation the transition state stochastic equation may be written

$$S_{i,\tau+1} = p_{i-1,i}S_{i-1,\tau} + \delta_i S_{i,\tau} + q_{i+1}S_{i+1,\tau} \tag{1.58}$$

or, recalling (1.53)

$$S_{i,\tau+1} = (1 - q_i - p_i)S_{i,\tau} + p_{i-1}S_{i-1,\tau} + q_{i+1}S_{i+1,\tau}, \tag{1.59}$$

we have

$$S_{i,\tau+1} = S_{i,\tau} - q_i S_{i,\tau} - p_i S_{i,\tau} + p_{i-1} S_{i-1,\tau} + q_{i+1} S_{i+1,\tau}. \tag{1.60}$$

Naming

$$\begin{cases} t_i = p_{i,} S_i \\ r_i = q_i S_i \end{cases} \tag{1.61}$$

we got by substitution

$$S_{i,\tau+1} = S_{i,\tau} - r_{i,\tau} - t_{i,\tau} + t_{i-1,\tau} + r_{i+1,\tau}. \tag{1.62}$$

Since the resolution of this transition stochastic difference equation is not easy it is convenient to approach it to a continuous differential equation. Naturally, we are perfectly aware that the separation of states going to infinite makes, in this approach to describe reality, no much sense. At a certain level of separation there occurs a chance in the scale of description of the reality. Obviously, we know that in the complex physics, the physics of the Becoming, there is no scale invariance. From a certain level down of description the being ceases to exist as such. Indeed we are before another entirely different realm. Even so, and with these considerations in mind it is still convenient form a pragmatic point of view to derive the stochastic differential equation. This equation may prove very useful if we were caution in the utilization of it.

In order to derive from the stochastic finite difference equation the differential equation we need to define the fundamental variables. If we were dealing with a classic causal description the fundamental variables would be naturally the space and the related chronological time. Since we are at a much more deep level of description of reality were space and chronological are no longer the basic concepts we need to find the more basic fundamental variables. From what was seen we may infer which these fundamental variables may be. These fundamental basic variables are: the true time, τ standing for the becoming and the fundamental frequency ξ, naturally interconnected with the true time. This basic frequency is nothing more than the pattern repetition in the becoming. From the differences in the pattern repetition, from the difference in frequency, occurring in the becoming it is possible to individualize the beings that is, to tell the difference among the different kinds of states.

In these conditions the generic state

$$S \equiv S(a, b, c, d, e, f, ..., N) \tag{1.63}$$

function of many specific variables and parameters, $a, b, c, d, ...$ is in last instance function only of the true time and the basic frequency

$$S = S(\xi, \tau), \tag{1.64}$$

since each variable and parameter depends also on them

$$a = a(\xi, \tau),\ b = b(\xi, \tau),\ c = c(\xi, \tau),\ d = d(\xi, \tau), ... \tag{1.65}$$

we are then allowed to write the transition stochastic equation (1.64)

$$S_{i,\tau+1} = S_{i,\tau} - r_{i,\tau} - t_{i,\tau} + t_{i-1,\tau} + r_{i+1,\tau} \tag{1.66}$$

which may also be written

$$S\xi, \tau + \tau_0 = S_{\xi,\tau} - r_{\xi,\tau} - t_{\xi,\tau} + t_{\xi-\xi_0,\tau} + r_{\xi+\xi_0,\tau} \tag{1.67}$$

where τ_0 and ξ_0 stand for minimum incremental values in the becoming. After expanding this formula in Taylor power series and making the cut off from τ_0^2 and ξ_0^3 we have after arranging the terms

$$\tau_0 S_\tau = -\xi_0(p_\xi - q_\xi)S - \xi_0(p-q)S_\xi + \frac{1}{2}\xi_0^2(p_{\xi\xi} + q_{\xi\xi})S + \xi_0^2(p_\xi + q_\xi)S_\xi + \frac{1}{2}\xi_0^2(p+q)S_{\xi\xi}. \tag{1.68}$$

Note that here, in the continuous approach, the lower index stands for the derivative

$$S_\tau = \frac{\partial S}{\partial \tau} \tag{1.69}$$

Now it is convenient to name the difference of the transition probabilities by

$$\mu(\xi) = p(\xi) - q(\xi) \tag{1.70}$$

and the sum

$$d(\xi) = p(\xi) + q(\xi) \tag{1.71}$$

So, we may have by substitution and after making the derivatives of these expressions

$$\frac{\tau_0}{\xi_0} S_\tau = \left(\frac{1}{2}\xi_0 d_{\xi\xi} - \mu_\xi\right) S + (\xi_0 d_\xi - \mu)\, S_\xi + \frac{1}{2}\xi_0 d S_{\xi\xi}. \tag{1.72}$$

By naming

$$A(\xi) = \frac{1}{2}\xi_0 d,\ \ B(\xi) = \xi_0 d_x - \mu,\ \ C(\xi) = \frac{1}{2}\xi_0 d_{\xi\xi} - \mu_\xi, \tag{1.73}$$

and by substitution into (1.72) we have finally the differential transition equation for the stochastic process

$$A(\xi)\frac{\partial^2 S}{d\xi^2} + B(\xi)\frac{\partial S}{\partial \xi} + C(\xi)S = \frac{1}{v_0}\frac{\partial S}{\partial \tau} \tag{1.74}$$

where we have made

$$v_0 = \frac{\xi_0}{\tau_0}. \tag{1.75}$$

In this continuous mathematical language the transition probabilities may also be written

$$\begin{cases} q(\xi) = \frac{I(\xi-\xi_0)}{I(\xi-\xi_0)+I(\xi)+I(\xi+\xi_0)} \\ \\ \delta(\xi) = \frac{I(\xi)}{I(\xi-\xi_0)+I(\xi)+I(\xi+\xi_0)} \\ \\ p(\xi) = \frac{I(\xi+\xi_0)}{I(\xi-\xi_0)+I(\xi)+I(\xi+\xi_0)} \end{cases} \tag{1.76}$$

Again expanding in Taylor power series and making the habitual cutoff we have by substitution

$$\begin{cases} q(\xi) = \frac{I-\xi_0 I_\xi+\frac{1}{2}\xi_0^2 I_{\xi\xi}}{3I+\xi_0^2 I_{\xi\xi}} \\ \\ \delta(\xi) = \frac{I}{3I+\xi_0^2 I_{\xi\xi}} \\ \\ p(\xi) = \frac{I+\xi_0 I_\xi+\frac{1}{2}\xi_0^2 I_{\xi\xi}}{3I+\xi_0^2 I_{\xi\xi}} \end{cases} \tag{1.77}$$

In this case and for this approximation $d(\xi)$ and $\mu(\xi)$ may be written

$$\begin{cases} \mu(\xi) = \frac{2l_0 I_\xi}{3I+l_0^2 I_{\xi\xi}} \\ \\ d(\xi) = 1 - \frac{I}{3I+l_0^2 I_{\xi\xi}} \end{cases} \tag{1.78}$$

In some cases it may prove convenient to make the approximation

$$3I + l_0^2 I_{\xi\xi} \simeq 3I, \tag{1.79}$$

giving for the parameters

$$\begin{cases} \mu(\xi) = \frac{2}{3} l_0 \frac{I_\xi}{I} \\ \\ d(\xi) = \frac{2}{3} \end{cases} \tag{1.80}$$

The reader interested in more particulars of the calculations may see analogous calculations in the work of one of us [4] HyperPhysics the unification of physics.

Now according to each particular form for the transition propensity we may, in principle be able to determinate, under the above indicated approximations, the mathematical form for describing approximately the state.

1.9 Conclusion

From the present work it may be gathered the Hyperphysics is a particular case of the more general approach of the Physics of Becoming that is, a Physics where space and correlated chronological time play no fundamental role. Yet Hyperphysics, the physics of the complex, stands for the nonlinear generalization of the traditional physics, based essentially on the linear Cartesian approach, such as quantum mechanics, relativity and classical physics that is, classical mechanics and electromagnetism. Even if the Physics of Becoming represents a step further in the comprehension of Reality in any way it invalidates the achievements of Hyperphysics. Just like Hyperphysics which does not denies the marvelous achievements of classical physics, namely the ones of classical mechanics. Only now we don't pretend that these important scientific achievements of the past are the last word, the absolute theories to describe Reality completely. They may prove more or less adequate to help us in the better understanding of reality at their own scales of adequacy and nothing more. No more these admirable theories, nor any eventually future better theory, built by man, may ever be considered as definitive, as final as absolute. Any theory, the best it may seem at a given moment of human history, has inevitably it own limitations. So, the Physics of Becoming does not invalidate Hyperphysics, where space and chronological time play a fundamental role. On the contrary, it even allows us to understand it better clarifying its true meaning in a much broader picture.

The observation and understanding of the interacting processes depends mainly on the conceptual and experimental tools available at a given stage of the evolution of mankind. These particular tools are the result of an optimal choice among the in principle large possibilities of other tools. Still these tools of space and chronological time have proven very adequate and convenient for helping us in the understanding of the accessible reality. This reality, this scale of observation, is acceded through our senses plus the extension of them. Traditional physics uses our body, imaging devices, cars, planes and so, giving an experimental accessible universe. This traditional experimental universe is very adequate described by the concepts of space and chronological time. When, as happened with quantum

physics, or more precisely with hyperphysics, this observable experimental realm increased dramatically, it is no wonder that the traditional tools of space and chronological time no longer were adequate to describe the situation.

In a way and in a certain sense the Physics of Becoming also integrates some apparently contradictory and incomprehensible features of orthodox quantum mechanics. Namely the collapse of the state vector which, as we know, states that out of a bunch of probabilities by the act of measurement, there occur the actualization, the realization of one of the potential states. In the physics of the Becoming there also occurs the emergence of given state out of a very large bunch of possible states. But now these states are real, in the sense that they are observer independent. They are not the making of the observer. In these conditions, emergence happens not from some strange and incomprehensible making of the observer consciousness but as a result of a natural very complex reciprocal interacting process.

The Physics of Becoming is the physics of the Unity. Space and chronological time play no fundamental role in it. So, in a deep sense there is no inside and no outside, we have only similar and diverse, that is, non similar with a large range of variation between the possible states. A state, a being, more or less complex, in this physics may be understood, using a metaphoric language, as a symphony where the diverse states, the diverse melodic structures, emerge and de-emerge giving origin to a constant becoming of new complex entities interacting reciprocally among them. New structures, new buildings, whole new architectures emerge and de-emerge. So, Life, in this broad general sense, is like a symphony, nothing more than a continuous becoming.

To conclude this work it is opportune to refer to a deep problem seemingly without a suitable solution that has been hunting mankind for some millennia. It is common knowledge that the Greek rationality faced the important problem of the nature of the Being. Parmenides and Zeno claimed that motion was an illusion of our senses, because a Being is something that is, consequently cannot change. For Heraclitus a Being is something that is in permanent becoming. Everything is in transformation that is, according to him, in motion. So, apparently there is a big dichotomy, a great void between these two extreme positions. One claiming that motion is an illusion, the other stating the opposite, that everything is motion. We believe that both thinkers were, in a certain sense, right. Indeed, both get some glints of the Truth. This confusion and apparent contradiction can be easily overcome if we look at the problem with the eyes of the Physics of Becoming.

Parmenides and Zeno and other thinkers were right when they claimed that the motion is an illusion of our senses. Motion, in this context, is to be understood

as an alteration of something occurring in space that is, a change in space. This motion is measured relating positions in space with time. By its turn this time, the chronological time, is calculated with the help of a clock. A clock is a device that evaluates chronological time by measurements made in space. That means that we are before a vicious circle. Motion is a relation between space and time but also time, chronological time, depends on space.

Heraclitus by its turn rightly gasped that a Being is in permanent changing, but only now this changing has nothing to do with space and chronological time. This changing, this becoming is something much more basic and beyond the reach of the secondary auxiliary concepts of space and chronological time.

So, Parmenides and Zeno were right when they said that motion and consequently space and chronological time are an illusion of our senses and Heraclitus was also right when he sustained that everything is in permanent becoming. In this sense the great contradiction faced by the classic Greeks was solved in a very satisfactory way. For this it is necessary, as we have stressed, do not stand tied by the auxiliary and limiting concepts of space and chronological time. The problem lies precisely in wanting to find an explanation in the restrictive conceptual box of the space and chronological time for something that is beyond its reach. The greatness of those thinkers of the past was that although the concrete fact that they lived immersed in conceptual framework of space and chronological time yet they glimpse some important elements of the Truth.

1.10 References

1 – JR Croca and MM Silva, The Concept of Time, in A New Vision on Physics, Eurhythmy, Emergence and Nonlinearity, Eds. JR Croca and JE Araújo, CFCUL, Lisboa, 2010, pags. 397-399.

2 – D.W. Pohl, W. Denk, and M. Lanz, Optical stethoscopy image recording with resolution ?, Appl. Phys. Lett. Vol. 44, no 7 1984, pag. 651. F. Zenhausern, M.P. O'Boyle and H.K. Wickramasinghe, Appl. Phys. Lett. 65(1994)1623. B.Hecht, H. Bielefeld, Y. Inouye, D.W. Pohl and L. Novotny,J. Appl. Phys. 81(1997)2492.

3 – G. Nimtz, A. Enders and H. Spieker, in Wave and Particle in Light and Matter,

edited by Van der Merwe and A. Garuccio, Plenum, New York 1993; G. Nimtz, Phys. Rev B 47(1993)9605; A. Enders, E. Recami, Found. Phys. 31(2001)1119; S. Longhi, M. Marano, P. Laporta and M. Belmonte, Phys. Rev. E, 64(2001) 1. E. H. Hauge and J. A. Støvneng, Rev. Mod. Phys. 61(1989)917; V. S. Olkhovsky and E. Recami, Phys. Rep. 214(1992)339.

4 – J.R. Croca, HyperPhysics, The Unification of Physics in A New Vision on Physics, Eurhythmy, Emergence and Nonlinearity, Eds. JR Croca and JE Araújo, CFCUL, Lisboa, 2010, pag. 1-106.

5 – C. Schaefer and G. Gross, Ann. Physik, 32(1910)648.

6 – D. Coon, Am. J. Phys.34(1966)240.

7 – G. Gamow, Zeits. f. Physik, 51(1928)204.

8 – G. Binning and H. Roher, Reviews of Modern Physics, 59(1987)615.

9 – H. Heiselmann, D.W. Pohl, Appl. Phys. A, 59(1994)89.

10 – A. Grossmann and J. Morlet, SIAM J. Math. Anal. 3, (1989) 723; C.K Chui, An Introduction to Wavelets, Academic Press, N.Y. 1992.

11 – L. de Broglie, The Current Interpretation of Wave Mechanics: A Critical Study, (Elsevier, Amsterdam, 1969).

12 – JR Croca, Towards a nonlinear quantum physics, World Scientific, London, 2003.

13 – The Greek word acron was suggested to me by my dear friend the Portuguese Philosopher Professor Eduardo Chitas.

14 – R.N. Moreira, The crisis in theoretical physics, science, philosophy and metaphysics, in A New Vision on Physics, Eurhythmy, Emergence and Nonlinearity,

Eds. JR Croca and JE Araújo, CFCUL, Lisboa, 2010, pag. 255-312. G. M. Santos, Between two worlds. Nonlinearity and a new mechanistic approach, in A New Vision on Physics, Eurhythmy, Emergence and Nonlinearity, Eds. JR Croca and JE Araújo, CFCUL, Lisboa, 2010, pag. 313-330.

15 – C. H. Benett et al. Phys. Rev. Lett. 70(1993)1895-1899 ; D. Bouwmeester, J. W. Pan, K. Mattle, M. Eibl, H. Weinfurter, A. Zeillinger, Nature, 390(1997)575-579. 16 - M. Alcubierre, The warp drive: hyper-fast travel within general relativity, Class. Quantum Grav. 11 L73, 1994. Puthoff, H. E. (2002), "Polarizable-Vacuum Approach to General Relativity", in Gravitation and Cosmology: From the Hubble Radius to the Planck Scale, eds. R. L. Amoroso, G. Hunter, M. Kafatos, and J.-P. Vigier, Kluwer Academic Publ., Dordrecht, the Netherlands, pp. 431-446.

17 – This concept of propensity, as far as we know, was first introduced by Karl Popper: K. Popper, Quantum mechanics and the schism in physics, Routledge, London, 1989.

Chapter 2

The Concept of Space and the Philosophy of Geometry

Rui Sampaio da Silva
D.H.F.C.S.
University of the Azores
9500 Ponta Delgada
and
Philosophy Centre of the University of Lisbon
Portugal
(rsilva@uac.pt)

The distinction between analytic and synthetic judgements has played an important historical role in the domain of philosophy of mathematics. An early formulation of the distinction can be found in Leibniz's writings, more precisely in his distinction between "truths of reason", understood as propositions that are necessary or true in all possible worlds, and "truths of fact", contingent propositions whose opposite is possible. Hume, in turn, established a fundamental distinction between two different kinds of objects of thought: "relations of ideas" and "matters of fact" (cf. Hume 1975: 25-26) [6]. The first kind embraces the fields of geometry, algebra and arithmetic, consisting of affirmations which are "either intuitively or demonstratively certain", whereas the latter kind is constituted by propositions that depend on experience and whose denial does not involve contradiction.

Kant revised such a distinction, arguing for the existence of three fundamental types of judgement: analytic judgements, which are based on the principle of contradiction and in which the predicate is contained in the concept of the subject; synthetic judgements, which are informative because the predicate adds something

to the concept of the subject; and, finally, synthetic *a priori* judgements, which constitute, according to Kant, the knowledge that we have in the domains of geometry, arithmetic and metaphysics. More precisely, arithmetic, to the extent that it involves numerical sequences or successions, would be based on time, understood as a form of pure intuition, whereas geometry would be based on another pure form of intuition; space. The knowledge obtained in these domains is, still according to Kant, *a priori*, but not analytic, because the propositions of geometry and arithmetic are genuinely informative.

However, Kant's account of analyticity, based on the metaphor of containment (in the analytic judgement, a predicate is contained in the concept of the subject), is vague. Dissatisfied with Kant's definition of analyticity, Frege, an important voice in the debate on analyticity, decided to conceive of analytical propositions as those propositions that can be proved on the basis of logical laws and definitions; they are either logical truths or reducible to logical truths. Synthetic propositions were defined in a contrastive way: "If, however, it is impossible to give the proof without making use of truths which are not of a general logical nature, but belong to the sphere of some special science, then the proposition is a synthetic one" (Frege 1980: 4) [4]. In opposition to Kant, Frege claimed that analytic propositions can have an informative character, rendering unnecessary an appeal to synthetic *a priori* judgements in arithmetic. According to Frege, a mathematical equation is genuinely informative, by showing that expressions with different *senses* may have the same *reference*. Similarly, the expressions "morning star" and "evening star" have the same reference (the planet Venus), but have different senses; they present different ways of conceiving of Venus. For this reason, the sentence "the morning star is the evening star", far from being a mere tautology (like "the morning star is the morning star") is genuinely informative. Part of the Kantian motivation to consider arithmetic as a non-analytic body of knowledge is thereby undermined. However, Frege claimed that geometry, unlike arithmetic, is constituted by synthetic propositions, because it is possible to construct different geometric theories departing from different sets of axioms.

Finally, and in order to finish this historical foray, one must highlight the important role played by the analytic/synthetic distinction in the logical positivism. The representatives of this philosophical movement rejected the Kantian notion of synthetic *a priori* judgements, because it presupposes cognitive faculties which were incompatible with their professed empiricism. They recognized only the existence of analytic and synthetic (a posteriori) propositions, and to these two kinds of propositions correspond, respectively, two forms of human knowledge: the logical-mathematical knowledge and the empirical knowledge. As heirs of the empiricist tradition, logical positivists claimed that human knowledge comes from experience,

but this central empiricist claim raises serious problems in the field of logic and mathematics, because these disciplines do not seem to be based on sense experience. J. S. Mill, a determined empiricist, decided to bite the bullet, so to speak, and elaborated an account of logic and mathematics as disciplines based on experience, but his strategy was largely rejected, even among empiricists. The logical positivists solved this problem by claiming that logic and mathematics are constituted by analytic propositions and by offering a new conception of analyticity that did not appeal to obscure or mysterious cognitive faculties. According to Carnap, for instance, analytic propositions are propositions that express the rules that constitute a language; their *a priori* character could be, thus, explained without violating the empiricist conception of knowledge. In the same vein, another influential advocate of logical positivism, Ayer (1936)[1], defined the analytic propositions as propositions that are true in virtue of the meaning of their terms.

The analytic/synthetic distinction has played, as we have just seen, a crucial role in the history of philosophy and, in particular, in the philosophy of mathematics. For this reason, Quine's critique of this distinction in his famous article "Two Dogmas of Empiricism" (1953) [9] occupies an important place in the debate on analyticity. Quine developed two argumentation lines against analyticity: on the one hand, he argued that analyticity belongs to a circle of interdefinable, but equally obscure notions, such as synonymy, necessity or semantic rule; on the other hand, he argued that any proposition can be abandoned (a point that contradicts the traditional account of analytic propositions, taken as necessarily true) and that any proposition can be maintained, even in the face of apparently hostile evidence, by making the necessary adjustments in the theoretical system:

> It becomes folly to seek a boundary between synthetic statements, which hold contingently on experience, and analytic statements, which hold come what may. Any statement can be held true come what may, if we make drastic enough adjustments elsewhere in the system. (...) Conversely, by the same token, no statement is immune to revision. Revision even of the logical law of the excluded middle has been proposed as a means of simplifying quantum mechanics. (Quine 1953: 43) [9]

The so-called Duhem-Quine thesis underlines this second argumentation line. According to this thesis, one cannot test empirically an isolated hypothesis, but only sets of hypotheses or propositions:

> In sum, the physicist can never subject an isolated hypothesis to experimental test, but only a whole group of hypotheses; when the experiment is in disagreement with his predictions, what he learns is that at

> least one of the hypotheses constituting this group is unacceptable and ought to be modified, but the experiment does not designate which one should be changed. (Duhem 1991: 187) [3]
>
> Our statements about the external world face the tribunal of sense experience not individually but only as a corporate body (Quine 1953: 41) [9].

The Duhem-Quine thesis has far-reaching epistemological consequences; when the experience contradicts a theory, the scientist can always choose between different ways to reconcile the theory with the observational data. As a result, the Duhem-Quine thesis supports another key epistemological Quinean thesis; the underdetermination of theory by data. In fact, if there is always more than one way to adjust our theoretical system and to harmonize it with experience, it seems plausible to conclude that it is always possible to frame more than one theory for the same set of observational data (cf. Quine 1975: 313) [10]. According to this holistic view of science, the propositions of logic and mathematics do not have an intrinsic epistemological privilege; if they seem to be unarguably true, it is because they are entrenched in the centre of the system of science, and as such they are, in practice, immune to processes of revision and correction of scientific propositions.

The debate on the analytic/synthetic distinction is relevant to understand the philosophical reflection on geometry which was triggered by the emergence of non-Euclidian geometries in the 19th century. These geometries raised an important epistemological problem regarding the possibility of empirical tests for geometric theories. One should point out, in this regard, that Einstein, in his general theory of relativity, had used a non-Euclidian geometry and had proposed a geometrization of gravity, understood as a curvature of spacetime. In the context of the present discussion, Poincaré's conventionalist defence of the Euclidian geometry against its rivals in the 19th century acquires a particular relevance. Poincaré recognized that the non-Euclidian geometries are consistent and that it is possible to conceive of a possible world in which they were true. However, and in opposition to an empiricist perspective, he claimed that it is not possible to choose the best geometry on the basis of observations and experiences. According to Poincaré, the same set of empirical data can be accommodated by many logically incompatible geometric theories. This being the case, one should simply choose, by convention, the simplest geometry; the Euclidian one. The Euclidian geometry is not empirically refutable, because even if our observations showed that the paths of light rays (the physical expression of a straight line) were not in conformity with the principles of the Euclidian geometry, it would still be possible to maintain it, by correcting our physical theory and, in particular, the laws of optics:

> what we call a straight line in astronomy is simply the path of a ray of light. If, therefore, we were to discover negative parallaxes, or to prove that all parallaxes are higher than a certain limit, we should have a choice between two conclusions: we could give up Euclidian geometry, or modify the laws of optics, and suppose that light is not rigorously propagated in a straight line. (...) Euclidian geometry, therefore, has nothing to fear from fresh experiments. (Poincaré 1952: 73) [8].

In other words, we cannot confront a pure geometric theory with experience, but only a collective body of geometric and physical propositions or hypotheses. Given this interdependence between geometry and physics, it would always be possible to change a geometry by adjusting the corresponding physical theory. As a result, and as Poincaré himself stressed, our choice of a geometry is guided by pragmatic considerations; we choose a geometry not because it is true, but because it is advantageous.

Poincaré's conventionalism is a provocative epistemological position, and, as such, it has been the target of important criticisms from several philosophers. A case in point is Hans Reichenbach, one of the main figures of the philosophy of geometry in the 20th century[1]. A crucial starting point of his philosophical reflection on geometry consists in the idea that geometric measures depend on "coordinative definitions", which correlate concepts with physical objects; an example thereof is the definition of a "geodesic between two points" as "the path of a light ray in a vacuum". In the following passage from the *Philosophy of Space and Time*, Reichenbach clarifies the notion of "coordinative definition":

> Physical knowledge is characterized by the fact that concepts are not only defined by other concepts, but are also coordinated to real objects. This coordination cannot be replaced by an explanation of meanings, it simply states that this concept is coordinated to this particular thing. In general this coordination is not arbitrary. (...) But certain preliminary coordinations must be determined before the method of coordination can be carried through any further; these first coordinations are therefore definitions which we shall call coordinative definitions. They are arbitrary, like all definitions; on their choice depends on the conceptual system which develops with the progress of science (Reichenbach

[1]Reichenbach is sometimes interpreted as a conventionalist, but Putnam, in his paper "The refutation of conventionalism", argued convincingly that conventionalism "need not, in fact, follow from Reichenbach's work, and does not follow from the best of his work" (Putnam 1975: 153). Sklar (1977) also interpreted Reichenbach as an empiricist critic of Poincaré's conventionalism.

1958: 14) [12].

Although Reichenbach recognized that it is possible to replace a geometry with another one by changing the respective coordinative definitions, he thought that two geometric theories that are intersubstitutable through redefinitions of the terms are not really two different theories, but only two different expressions of the same theory[2]. This is already a departure from Poincaré's conventionalism. Moreover, Reichenbach established, in *The Philosophy of Space and Time*, an important distinction between universal forces (which affect in the same way all bodies)[3] and differential forces, a distinction that helped him avoid the relativistic consequences of Poincaré's conventionalism. In fact, if we allow a physicist to vary his/her hypotheses regarding the universal forces that act in a universe, he/she can change freely and arbitrarily its geometry. Poincaré himself had presented an example that illustrates this point: let us imagine a universe that consists of a two-dimensional disk with a constant temperature at the centre, whereas the temperature at the circumference is an absolute 0º; let us also imagine that the two-dimensional inhabitants of this universe try to determine its geometry using rigid rods and assuming that the length of the rod remains invariant in the different regions of the disk; they will naturally conclude that their world is an infinite Lobachevskian plane. However, a native physicist could claim that this universe is, appearances notwithstanding, a finite Euclidian plane, where the length of the measuring rods diminishes with a decrease in temperature; in other others, the measuring rods (and other objects) contract themselves when they travel from the centre to the circumference of the disk, and for this reason the contraction of the bodies is not perceptible or measurable. How could the inhabitants of this world choose the right geometry? To avoid such an arbitrariness in physical geometry, Reichenbach claimed that the correct method in physics would be to reduce to zero the universal forces (as is the case of temperature in Poincaré's famous parable) and to consider only the action of differential forces. Without such a rule, it would not even be possible to define the notion of a rigid body[4]. In Sklar's words:

[2]Sklar (1977: 97) gives us a good formulation of this point: "The appearance of two 'incompatible' total theories is misleading. Properly speaking, there is only one theory, although it is written in two different ways. The confusion comes about, because, in the two expressions of the same theory, words are being used with different meanings."

[3]Putnam (1975: 173) characterizes universal forces, in Reichenbach's sense, as forces that "(1) the total deformation they produce upon any body is the same, independently of the internal resistance to deformation of that body; (2) the forces are permanently associated with regions of space; (3) the forces have no sources and no shields".

[4]Reichenbach (1958: 22) defines a rigid body in the following terms: "Rigid bodies are solid bodies that are not affected by differential forces, or concerning which the influence of differential forces has been eliminated by corrections; universal forces are disregarded. (...) Without such a rule the rigid body cannot be defined. (...) No object is rigid relative to universal forces."

> To save a particular geometry by postulating a universal force is not to save one part of physics by making "real changes in the remainder". (...) To postulate a nonzero universal force would simply be to change one's coordinative definitions. The modified theory would not really hypothesize a new geometry for spacetime at all, it would simply rewrite the old geometric theory in a potentially misleading way (Sklar 1977: 100) [14].

Reichenbach's position can be assessed in the light of the analytic/synthetic distinction. His book *The Philosophy of Space and Time* was written before Quine's influential attack against this distinction in "Two Dogmas of Empiricism". It is not, therefore, surprising that Reichenbach relies on a distinction between definitional (analytic) and synthetic (empirical) elements in physical geometry. As Putnam put it:

> Reichenbach *identified* the problem of specifying the mechanism of reference for magnitude terms with the problem of separating definitional and empirical elements in scientific theory. For Reichenbach, the analytic-synthetic distinction was essential. The whole job of the philosopher reduced to the job of deciding which sentences in scientific theory are really analytic, appearances to the contrary, and which ones are really synthetic. But he was led to this conception of the philosopher's job precisely because he identified the problem of separating analytic and synthetic, or definitional and empirical, elements in science, with the problem of explaining the mechanism of reference of scientific terms (Putnam 1975: 175) [13].

According to Putnam, Reichenbach was on the right track, but he was betrayed by his reliance on the analytic/synthetic distinction (which is present in his talk of "coordinative definitions"). Putnam, on the contrary, is sympathetic to Quine's critique of the distinction and to his insight that "meaning, in the sense of reference, is a function of theory" (Putnam 1975: 164-5). This being the case, it is pointless to pick out a class of propositions that are true in virtue of its meaning (analytic propositions); and instead of fixing the reference of terms simply by convention, we can fix it by coherence. This notion is understood by Putnam (1975: 165) [13] in the following terms: internal coherence means "matters as simplicity, and agreement with intuition"; external coherence refers, in turn, to "agreement with experimental checks". Such a notion of coherence is used by Putnam to complement Reichenbach's reflection on geometry and to refute conventionalism. We can use the above mentioned Poincaré's parable to illustrate now this (anticonventionalist) point: a physical geometry that assumes the existence of universal forces and claims that bodies expand or shrink uniformly when they travel through the universe

entails very complicated laws of physics, and according to the Putnamian criterion of coherence it cannot be considered equivalent to a simpler physical geometry, even if both geometries are equally compatible with all observational data. Against Reichenbach, Putnam (1975: 174) [13] claims that the rejection of universal forces "does not single out a unique geometry plus physics", but he also claims that this should not constitute a major problem for Reichenbach, provided that his approach is complemented by a rejection of the analytic/synthetic distinction and by a coherence account of the reference of scientific terms.

There is another aspect of Quine's epistemological reflection which is relevant in the present context, because it contributes to minimize the risk of epistemological conventionalism by helping us to distinguish between better and worse hypotheses. In his book *Web of Belief* (co-authored with Ullian) [11], Quine stressed the importance of some fundamental "virtues" of scientific hypotheses, like conservatism (when we have to revise a theoretical system, we should avoid, if possible, substantial corrections), modesty[5], simplicity, generality (we should prefer the hypothesis that has a broader range of application) and refutability. Other epistemological principles that are relevant to the present discussion are the principle according to which we should avoid (unless there is a good justification) *ad hoc* hypotheses or the principle that one should favour hypotheses that lead to successful predictions or to the discovery of new facts; Einstein's conjecture regarding the curvature of light rays in the vicinity of the Sun is a good example thereof.

In sum, the Duhem-Quine thesis may seem to be, at first sight a form of conventionalism that would inevitably infect our account of physical geometry, but, as shown by Putnam, we can draw on insights from Quine and Reichenbach to avoid conventionalism.

[5]"One hypothesis is more modest than another if it is weaker in a logical sense: if it is implied by the other, without implying it" (Quine/Ullian 1978: 68).

Bibliography

[1] AYER, A. J. 1936. *Language, Truth and Logic*. London: Gollancz.

[2] CARNAP, R. 1937. *The Logical Syntax of Language*. London: Routledge.

[3] DUHEM, P. 1991. *The Aim and Structure of Physical Theory*. Princeton, NJ: Princeton University Press.

[4] FREGE, G. 1980. *The Foundations of Arithmetic*. London: Blackwell.

[5] KANT, I. 1999. *Critique of Pure Reason*. Cambridge: Cambridge University Press.

[6] HUME, D. 1975. *Enquiries Concerning Human Understanding and Concerning the Principles of Morals*. Clarendon Pres: Oxford.

[7] JUHL, C. and LOOMIS. E. 2010. *Analyticity*. London: Routledge.

[8] POINCARÉ, H. 1952. *Science and Hypothesis*. Mineola, NY: Dover Publications.

[9] QUINE, W. V. O. 1953. *From a Logical Point of View*. Cambridge, MA: Harvard University Press.

[10] —— 1975. *"On Empirically Equivalent Systems of the World"*, Erkenntnis 9, 313-28.

[11] QUINE, W. V. O. and ULLIAN, J. S. 1978 [1970]. *The Web of Belief*. New York: McGraw-Hill.

[12] REICHENBACH, H. 1958. *The Philosophy of Space and Time*. Mineola, NY: Dover Publications.

[13] PUTNAM, H. 1975. *Mind, Language and Reality*. Cambridge: Cambridge University Press.

[14] SKLAR, L. 1977. *Space, Time and Spacetime*. Berkeley: University of California Press.

Chapter 3

Is it still possible to uphold a description of physical phenomena in space and time ?

Mário Gatta
Departamento de Matemática
Universidade dos Açores
9500 Ponta Delgada
and
Centro de Filosofia das Ciências da Universidade de Lisboa
Campo Grande, Ed. C8
1749-016 Lisboa
Portugal
(mgata@uac.pt)

3.1 Abstract

Any program of physical research pretending to describe matter in physical, three-dimensional space, free from instantaneous action-at-a-distance and satisfying causality has to address upfront the traditional, orthodox philosophies of quantum physics, which we here subsume, in their various forms, under the label "Copenhagen interpretation". One instance of such an attempt in quantum mechanics goes by the name of the theory of the double solution, initiated by Louis de Broglie. Another, in its stead, is the eurhythmic physics programme being developed by

José Croca and his group at CFCUL and aiming at a complete description of physical reality by conceptual and, especially, methodological extensions of early ideas in quantum mechanics. In this work we review some past efforts in dealing with some of those difficulties, with the purpose of claiming that such attempts are not doomed *ab initio*, despite common understanding to the contrary. In writing it, we have in mind the physicist and the philosopher who are willing to take into consideration the existence of possibilities that run against the majority view in fundamental domains of physics. These possibilities by no means constitute a coherent whole, at present, but we believe that they might open the way for developments that will congregate the required properties in a future theory.

3.2 Introduction

It is a common pedagogical strategy to "demonstrate" the unphysical character of the wave function Ψ in elementary quantum mechanics by appealing to the impossibility of expressing it for a system of particles in physical, three-dimensional space. And yet, even before that stage, one typically confronts the celebrated two-slit experiment in which particles impinge, one by one, on a two-slit wall and are collected on the other side, forming an arrival distribution that shows the bright and dark fringes that constitute, after all, an interference pattern. According to the common view, this particular phenomenon, "at the heart of quantum mechanics", "is impossible, absolutely impossible, to explain in any classical way" [1]. Still, it is difficult not to take as physically real, as much as the particles themselves, or indeed the experimental setup, the wave that is somehow associated with each particle. Otherwise, how could it "perceive" the presence of the wall and of the two slits ? And, in fact, experimental results with very small oil droplets mimicking the two-slit setup have been recently performed [2] and generated distribution histograms reproducing the interference patterns obtained long ago with photons, electrons and other particles. Given all this, is it too naive to expect the quantum waves to be real physical entities, evolving in three dimensional space and in time ?

3.3 Classical systems in configuration space

Our everyday physical space, containing macroscopic objects, being three dimensional, leads to the necessity of characterizing the location of a point body, i.e., a body whose dimensions are of no importance in some context, by three numerical

parameters - its coordinates - associated with our choice of a coordinate system. The simplest such choice is the rectangular coordinate system, defined by three mutually perpendicular axes, labeled X, Y, and Z for example, along which distances are measured in some chosen unit, common to all three - in meters, for example. Then, one can associate the spatial location of that material point (a "particle") by the three straight line distances between it and the planes defined by the three pairs os axes; its coordinate x would be given by the distance from the location of the particle to the (Y, Z) plane and similarly for the y and z coordinates; if the particle is in motion, the coordinates become functions of time, $x(t), y(t)$ and $z(t)$. But we are at liberty of choosing other coordinate systems in which the coordinates are not even distances, as long as we can always relate them unequivocally with the position of the particle in space. However, for that to be possible, it is necessary to always use three, and only three, parameters. For example, in the cylindrical coordinate system one defines the position of some particle by its distance ρ to the Z axis, the angle φ between the the plane that includes the point mass and the Z axis and the distance z to the (X, Y) plane. So, it is clear that even though one associates the dimensionality of space to possible directions for measuring distances, one is also at liberty to choose some other "curvilinear" coordinate system in which the parameters are not distances - in this example, we also have an angle, which may vary between 0 and 360 degrees (0 and 360 being the same, for the purpose at hand). Still, we can always translate back to distances and can shall take this possibility to be intimately associated with the concept of three-dimensional physical space.

Now if we have to deal with a system of two independent particles, say, the obvious generalization in establishing their position in space is to associate a set of coordinates (x_1, y_1, z_1) with the one labeled '1', and coordinates (x_2, y_2, z_2) with particle '2'. Of course, this presupposes that the point masses have an individual identity persisting in time. Again, we can very well use some other more convenient coordinate system, such as spherical coordinates for a system of two sufficiently small objects on the surface of the Earth (assumed spherical). But we can also characterize completely the location in physical space of these two particles by considering the total of 6 coordinates as an entity on its own, $(x_1, y_1, z_1, x_2, y_2, z_2)$, representing the (generally time-dependent) position of a single point in a 6-dimensional mathematical space, the so-called configuration space for this particular physical system, here spanned by 6 axes, X_1, Y_1, Z_1, X_2, Y_2, and Z_2. It is clear that for N independently moving particles we would consider a configuration space having $3 \times N$ dimensions, precisely because each one of the particles is able to move by itself in the $3D$ physical space.

So far, no advantage seems to come out of this abstraction. But not only are we not

restricted to using rectangular coordinates, we can also take advantage of possible existing physical restrictions on the motion of one or more particles in order to simplify the mathematical description of the system. These restrictions may be easier to define mathematically using coordinates other than the rectangular, or even the cylindrical or the spherical. But they always result in diminishing the number of parameters necessary to further define the state of the system under consideration. For example, for a system of just two particles such that their mutual distance is fixed, one can define the position of particle number '1' by its spherical coordinates $(r_1, \theta_1, \varphi_1)$ (relative to some suitable set of axes), and then the position of the second particle is uniquely defined by the two angles that give the direction of its position relative to the first. One then has not six but rather five coordinates, not all of them distances, necessary to completely define the position of the overall system in configuration space. Of course, each particle will occupy its own position in 3D physical space, and we can always attribute three cartesian coordinates (i.e., distances) to each of them.

The flexibility allowed by the use of curvilinear coordinate systems, in which coordinates no longer have to be distances, is conveniently generalized to accommodate whichever physical system is under study. For example, a pendulum hanging from a spring hanging, in turn, from the ceiling, can be described by a system of generalized coordinates given by the length of the spring, the angle it makes with the vertical, and the angle the pendulum makes with the vertical, for a total of three, and not six, generalized coordinates. Again, for a solid body such as a billiard ball, composed of millions of "point masses", we will need not 3 times those same millions generalized coordinates but only six, such as the (x_P, y_P, z_P) position of one of its point masses in physical space - conveniently, the center of mass - and the three angles between a system of orthogonal axes inside the body and fixed to it, and some appropriate external reference system of axes.

As before, one has a mixture of distances and angles constituting the set of coordinates that together form a configuration space appropriate to the system in question. Traditionally, these generalized coordinates are represented by letters q_1, q_2, ..., q_n, in which n is the number of them necessary to describe whatever system is being considered, giving also the dimension of the corresponding configuration space. Another major advantage, which does not concern us presently, is the fact that appropriate equations of motion of classical mechanics, formally independent of the particular choice of the set of generalized coordinates – the Euler-Lagrange equations – can be employed to solve for the motion of the system, first in configuration space and then, by "coordinate translation", back in physical 3D space.

It is clear, from these considerations, that the generalized coordinates are not

uniquely defined, that one can deal with systems in which none of them is a distance (e.g., substituting the spring in the example above by a fixed length rod), and also that their number is given by the number of degrees of freedom of the mechanical system under consideration and not necessarily by the number of particles therein present. It is also clear that the configuration space in classical mechanics is but a convenient, abstract way of studying the motion of some system represented by a single moving point in configuration space, with no pretense of some kind of ontological attribute, namely because the number of dimensions depends not only on the number of particles but also on the restrictions that may occur. However, no one contends that no matter how complicated the system, it still evolves in physical, ontological autonomous three-dimensional space, in which each dimension is associated with a distance, and also that, according to classical mechanics, it is always possible, in principle, to avoid the use of configuration spaces.

Furthermore, one can add that the theory of relativity, both the special and the general, did not overturn essentially the status of physical, three dimensional space, besides, of course, associating it intimately with the time coordinate and, in general relativity, endowing 'spacetime' with further properties, in result of the distribution of the masses present. One can say the relativity even accentuates the existence of physical space, now associated with the time coordinate.

All of this is well known and perhaps trivial. But what is possibly not so trivial is the fact that one can also uphold the view that we live not in the everyday 3 dimensional space but in a 3N dimensional physical space, in which N is given by the number of particles in the observable Universe, of the order of 10^{80} according to some estimates ([3] and references therein). The justification for this view would lie in the what is perceived as being the impositions of present day quantum mechanics.

3.3.1 The Hamilton-Jacobi equation for a system of N particles, in Classical Mechanics

There are several ways of setting up equations of motion for a system of particles in classical mechanics. In general, these particles will interact between themselves through fields they generate around each of them, and can also be subject to external fields, due to matter not accounted for in this particular system. If we have such a system of N particles, we can write down a corresponding system of N Newtonian equations of motion of the form

$$m_i \frac{d^2 \mathbf{R}_i}{dt^2} = \sum_{k=1}^{N} \mathbf{F}_{i,k} \left(\left| \mathbf{R}_i - \mathbf{R}_k \right|, t \right) + \mathbf{F}_i \left(\mathbf{R}_i, t \right), (i \neq k), \tag{3.1}$$

which is basically $m\mathbf{a} = \mathbf{F}$ for each particle in physical 3D space (in any appropriate system of coordinates), the total force $\mathbf{F}$ on each of them having two components, one through the mutual interaction potentials and the other through the external fields, respectively.

As mentioned above, it is frequently most convenient to set up an equivalent description not in 3D physical space but in some configuration space of, at most, 3N dimensions. We will review next the essentials of three such descriptions, associated with the Lagrange, the Hamilton, and the Hamilton-Jacobi equations of motion, building up each of them on the previous ones and all, ultimately, on the second law of Newtonian dynamics.

Taking the definition of the Lagrangian L of a system of particles as the difference between the total kinetic energy T and the total potential energy U (with internal and external contributions), we have $L(\{q_i\}, \{\dot{q}_i\}, t) = T(\{q_i\}, \{\dot{q}_i\}, t) - U(\{q_i\}, \{\dot{q}_i\}, t)$ with $\{q_i\}$ standing for the whole set of configuration space coordinates and $\{\dot{q}_i\}$ the corresponding time derivatives. For each one of the total of number of configuration space coordinates (which can be less than 3N), the corresponding Euler-Lagrange equation of motion is

$$\frac{d}{dt} \frac{\partial L}{\partial \dot{q}_i} - \frac{\partial L}{\partial q_i} = 0 \tag{3.2}$$

The solution of these equations gives the motion of the N particles, first in configuration space and then, after "translation", in physical 3D space.

From the Lagrangian function, we can define the Hamiltonian function of the system $H(\{q_i\}, \{p_i\}, t)$ in the phase space of generalized coordinates and momenta through the equality

$$H(\{q_i\}, \{p_i\}, t) = \sum_i p_i \dot{q}_i - L, \tag{3.3}$$

where $p_i = \partial L / \partial \dot{q}_i$ and the summation is performed over all the degrees of freedom of the system. In general, the Hamiltonian represents the total energy of the system, the sum of the kinetic and the potential energies. The Hamilton equations

of motion then are

$$\dot{q}_i = \frac{\partial H}{\partial p_i} \tag{3.4}$$

$$\dot{p}_i = -\frac{\partial H}{\partial q_i}, \tag{3.5}$$

and their resolution gives the motion of each particle in the system under consideration. Again, knowing the evolution of each generalized coordinate one can always get back the behavior in physical 3D space. Let us now define a function S, called the action of the system of particles, by the relation

$$\frac{dS}{dt} = L. \tag{3.6}$$

$S(\{q_i\}, \{\alpha_i\}, t)$ is a function of the whole set of generalized coordinates in configuration space $\{q_i\}$, the time t, and a set of constants $\{\alpha_i\}$ (actually, there can be one more constant, to be added to S). Taking advantage of the relation $\partial S/\partial q_i = p_i$, a generalized momentum component, we write down the Hamilton-Jacobi equation of motion of the system as

$$\frac{\partial S(\{q_i\}, \{\alpha_i\}, t)}{\partial t} + H(\{q_i\}, \{\partial S/\partial q_i\}, t) = 0 \tag{3.7}$$

Moving over to cartesian coordinates $\mathbf{R}_i = (X_i, Y_i, Z_i)$ still in configuration space, but assuming now that no constraints are being taken into consideration so that the number of degrees of freedom is equal to the total number of coordinates, i.e., 3N, and with the index i referring now to the i-th particle, we can rewrite the Hamilton-Jacobi equation as

$$\frac{\partial S(\{\mathbf{R}_i\}, \{\alpha_i\}, t)}{\partial t} + \sum_{i=1}^{N} \frac{1}{2m_i} \left[\left(\frac{\partial S}{\partial X_i} \right)^2 + \left(\frac{\partial S}{\partial Y_i} \right)^2 + \left(\frac{\partial S}{\partial Z_i} \right)^2 \right] + \frac{1}{2} \sum_{i,k=1}^{N} V_{ik}(|\mathbf{R}_i - \mathbf{R}_k|; t) + \sum_{i=1}^{N} V_i(\mathbf{R}_i; t) = 0 \ (i \neq k), \tag{3.8}$$

in which the first summation represents the kinetic energy of the system and the others the potential energy, due to interactions in the system and to interactions from outside fields, respectively.

But, as repeatedly stated, configuration space is merely a mathematical auxiliary concept and we still have, for each particle i, the Newtonian relation $m_i \mathbf{a}_i = \mathbf{F}_i$

in physical 3D space, so that ultimately we can also write down an Hamiltonian function for each particle as the sum of its kinetic and potential energies,

$$H_i = \frac{1}{2m_i}\left[\left(\frac{\partial S_i}{\partial X_i}\right)^2 + \left(\frac{\partial S_i}{\partial Y_i}\right)^2 + \left(\frac{\partial S_i}{\partial Z_i}\right)^2\right] + \sum_{k=1}^{N} V_{ik}(|\mathbf{R}_i - \mathbf{R}_k|; t) + V_i(\mathbf{R}_i; t),\ (i \neq k) \tag{3.9}$$

as well as the corresponding Hamilton-Jacobi equation for the action S_i of each particle i, now in physical 3D space :

$$\frac{\partial S_i}{\partial t} + \frac{1}{2m_i}\left[\left(\frac{\partial S_i}{\partial X_i}\right)^2 + \left(\frac{\partial S_i}{\partial Y_i}\right)^2 + \left(\frac{\partial S_i}{\partial Z_i}\right)^2\right] + \sum_{k=1}^{N} V_{ik}(|\mathbf{R}_i - \mathbf{R}_k|; t) + V_i(\mathbf{R}_i; t) = 0,\ (i \neq k). \tag{3.10}$$

This brief review of the main results of the classical mechanics of systems of particles was aimed at introducing the Hamilton-Jacobi equation of a system of interacting particles in configuration space and at pointing out the possibility of establishing also individual Hamilton-Jacobi equations for each particle in physical 3D space. This possibility will be crucial in the quantum description below, especially if one aims at a realistic interpretation.

3.4 The essentials of the causal interpretation, in a linear version and for just one particle in an external potential

Louis de Broglie introduced in 1924, in his Nobel prize winning doctoral thesis, the hypothesis that any material particle is physically associated with a real wave propagating in three dimensional space, such that a periodic phenomenon internal to the particle will always be in phase with that of the wave. From this basic premiss, he obtained the well known relation $p = h/\lambda$ between the linear momentum of the particle and the wavelength of the associated wave.

Progressively unsatisfied with the evolution of the concepts underlying the new quantum mechanics, especially the increasingly idealistic and abstract interpretation of the quantum mechanical entities, de Broglie made a first attempt at a different approach in which the non-physical wave Ψ would be kept due to its usefulness in the probabilistic interpretation, but another wave, this time having

physical reality, was introduced, the two being, in a simplified model, directly proportional. These ideas, albeit in a even more simplified form (the "pilot wave"), were unsuccessfully presented at the 1927 Solvay conference and put aside by de Broglie until around 1952, when occurred the publication of David Bohm's papers on a similar interpretation.

This 'theory of the double solution' (since both waves were solutions to the Schrödinger equation, at least in a simplified, linearized approach) put forward by de Broglie [4] considers that the wave associated with a quantum particle is indeed a real, physical object, propagating in physical 3D space as much as the particle itself, despite being proportional to a fictitious, purely mathematical wave Ψ, the latter being subject to the usual probabilistic interpretation and, as such, normalizable. Upon measurement of the position variable (and, in the end, all measurements are position measurements), what corresponds to the celebrated collapse of the wavefunction is the emptying of all the branches of the real physical wave with respect to the accompanying particle, except for the one that happens to carry the particle to its final, measured position. Consequently, there must exist empty branches of the overall physical wave, which should be detectable in principle by interference experiments [6].

The underlying motivation for the double solution theory was the staunch defense of the physical reality of the quantum entities, in a coherent whole with their observable behavior, such as the various interference experiments with matter waves : if the Ψ wave is but a mathematical construct, how can it interact with the double slit apparatus the experimenter sets up in his lab ? And this defense of the reality of the matter waves is to be extended, of course, from the situation in which just one particle is present to the situation of any number of particles, in such a way that the available end results given by the usual interpretation are still satisfied, since they are confirmed empirically.

It was soon realized by de Broglie that a proper consideration of the relation between the particle and its wave required the introduction of nonlinearities, to be described by a nonlinear differential equation, in place of the usual, linear Schrödinger equation. Among other advantages, the nonlinearity would allow for the propagation of quantum waves in vacuum without the spreading that occurs with the linear model. However, he never managed to arrive at this sought for nonlinear equation in a satisfactory manner, in part possibly because, even though he emphasized repeatedly the non-existence of waves of infinite extension, he also remained attached to the so-called "Fourier ontology" ([6], [6], etc), in which one has to take single frequency periodic phenomena, in space or in time, as being necessarily represented by waves of infinite extension, leading to all sorts of difficulties and paradoxes. A possible way out of this limiting ontology considers

the description afforded by finite waves associated with a single frequency, the wavelets. These can be shown to satisfy a nonlinear differential equation, the "master equation", that would take the place of the linear Schrödinger equation [6].

We do not pretend here to review the theory of de Broglie's and refer the reader, e.g., to his 1971 work with Andrade e Silva (see [7]). The main points, however, can be stated briefly. Calling, with J. Croca, Θ the physical quantum wave, such that $\Psi = c\,\Theta$, one has, in the linear approximation used by de Broglie, the usual Schrödinger equation

$$-\frac{\hbar^2}{2m}\nabla^2\Theta(\mathbf{r},t) + V(\mathbf{r},t)\Theta(\mathbf{r},t) = i\hbar\frac{\partial\Theta(\mathbf{r},t)}{\partial t} \tag{3.11}$$

for a single quantum particle in some field in which it possesses the potential energy $V(\mathbf{r},t)$. Incidentally, putting a minus sign on the time derivative of the r.h.s. of Schrödinger's equation would follow de Broglie's convention, but with no change whatsoever in physical content (it basically amounts to taking the complex conjugate of the traditional form). Now, following the usual procedure (that goes back to Madelung), we express the complex valued Θ wavefunction in polar form,

$$\Theta(\mathbf{r},t) = a(\mathbf{r},t)e^{i\varphi(\mathbf{r},t)/\hbar}, \tag{3.12}$$

with $a(\mathbf{r},t)$ and $\varphi(\mathbf{r},t)$ real functions of their arguments, plug it in the Schrödinger equation above and obtain

$$\frac{\partial a^2}{\partial t} + \nabla\cdot\left[a^2\,\nabla\left(\frac{\varphi}{m}\right)\right] = 0 \tag{3.13}$$

$$\frac{\partial\varphi}{\partial t} + \frac{1}{2m}(\nabla\varphi)^2 + V - \frac{\hbar^2}{2m}\frac{\nabla^2 a}{a} = 0, \tag{3.14}$$

with the addition of the guidance ("guidage") condition

$$\mathbf{v}_1 = \frac{\partial\mathbf{R}_1}{\partial t} = \frac{1}{m}\nabla\varphi(\mathbf{r},t)|_{\mathbf{r}=\mathbf{R}_1} \tag{3.15}$$

where $\mathbf{R}_1$ is the actual position of this particle.

It can be easily seen that the first resulting equation, (3.13) above, expresses the conservation of a "quantum fluid", whereas the second, (3.14), constitutes a quantum pseudo-Hamilton-Jacobi equation, "pseudo" in the sense that the spatial independent variable is the generic 3D-space point, $\mathbf{r}$, and not the particle position, here denoted by $\mathbf{R}_1$. This circumstance is reflected in the substitution explicit in the guidance condition above (3.15). Furthermore, and most importantly,

the quantum Hamilton-Jacobi equation above includes the quantum potential, $Q(\mathbf{r},t) = -(\hbar^2/2m)(\nabla^2 a/a)$ coupling the two differential equations through the amplitude $a(\mathbf{r},t)$, and which, obviously, will have to be solved simultaneously with the conservation equation. At this point it is appropriate to mention that the Eurhythmic Physics proposed by Croca is, at this level of mathematical treatment, associated not with the linear Schrödinger equation above, but with a nonlinear version,

$$-\frac{\hbar^2}{2m}\nabla^2\Theta(\mathbf{r},t) + \frac{\hbar^2}{2m}\frac{\nabla^2\sqrt{\Theta\Theta^*}}{\sqrt{\Theta\Theta^*}} + V(\mathbf{r},t)\Theta(\mathbf{r},t) = i\hbar\frac{\partial\Theta(\mathbf{r},t)}{\partial t} \tag{3.16}$$

that, upon the same transformation, generates a Hamilton-Jacobi equation without the quantum potential contribution. But its underlying description is, in reality, more fundamental and does not start from some differential equation but rather from a stochastic modeling of the particles (dubbed "acrons") and their accompanying waves in mutual non-linear interaction within themselves and with other particle-wave entities, without introducing the usual concepts of interaction potentials or forces.

Now, if we suppose that the one-particle wavefunction Θ is in fact a physical, objective wave, then the same must be naturally upheld if we deal with a system of quantum particles. Achieving a proper description of a system of N quantum particles, along with the associated waves, was precisely the aim of the Ph.D. thesis defended in the University of Paris, in 1960, by the Portuguese physicist João Andrade e Silva [8]: *"... il nous faut trouver une représentation des systèmes dans l'espace physique capable d'expliquer la réussite du formalisme habituel dans l'espace de configuration ..."*. In spite of this early effort, and even earlier works by de Broglie himself, the fact is that most physicists seem to be unaware of them : *In addition it should be noted that the concept of the double solution has never been extended to the many-body system, nor is there any idea available as to how this is to be done* [9]. This fact increases our belief that it could be worthwhile to revive these attempts at a more realistic description of quantum phenomena.

3.5 System of two interacting particles in physical space

We review the main points of the thesis presented in 1960 by Andrade e Silva, in Paris [8]. Its main purpose was to show that an appropriate description of systems of distinct quantum particles in mutual interaction in physical 3D space was possible, in such a way that the usual description in configuration space, by way

of the multi-particle Schrödinger equation, would be obtainable, as an impoverished description of the physical situation. The starting assumption was that we can attribute a specific physical wave (Θ in our present notation, emphasizing its physical character) to each particle, even if in interaction with others, and write, in physical 3D space ($\mathbf{r} = (x, y, z)$),

$$\Theta_1(\mathbf{r}, \mathbf{R}_2(t); t) = a_1(\mathbf{r}, \mathbf{R}_2(t); t) e^{i\varphi_1(\mathbf{r}, \mathbf{R}_2(t); t)/\hbar} \tag{3.17}$$

$$\Theta_2(\mathbf{r}, \mathbf{R}_1(t); t) = a_2(\mathbf{r}, \mathbf{R}_1(t); t) e^{i\varphi_2(\mathbf{r}, \mathbf{R}_1(t); t)/\hbar}. \tag{3.18}$$

The arguments in the assumed Θ waves above, both in the amplitudes $a(\mathbf{r}, \mathbf{R}(t); t)$ and in the phases $\varphi(\mathbf{r}, \mathbf{R}(t); t)$, reflect the propagation in physical 3D space, through the variable $\mathbf{r}$, as well as the interaction with the other particle, through the dependence on its position, $\mathbf{R}(t)$. It is clear that all speeds are assumed sufficiently small to allow for a nonrelativistic treatment.

Along with the essential physical assumption above, it was also assumed that the amplitudes and the phases of these waves satisfy, once more, a set of coupled differential equations of the form

$$\frac{\partial a_1^2}{\partial t} + \nabla \cdot \left[a_1^2 \left(\frac{\nabla \varphi_1}{m_1} \right) \right] = 0 \tag{3.19}$$

$$\frac{\partial \varphi_1}{\partial t} + \frac{1}{2m_1} (\nabla \varphi_1)^2 + V(\mathbf{r} - \mathbf{R}_2(t)) - \frac{\hbar^2}{2m_1} \frac{\nabla^2 a_1}{a_1} + Q_1' = 0 \tag{3.20}$$

$$\frac{\partial a_2^2}{\partial t} + \nabla \cdot \left[a_2^2 \left(\frac{\nabla \varphi_2}{m_2} \right) \right] = 0 \tag{3.21}$$

$$\frac{\partial \varphi_2}{\partial t} + \frac{1}{2m_2} (\nabla \varphi_2)^2 + V(\mathbf{r} - \mathbf{R}_1(t)) - \frac{\hbar^2}{2m_2} \frac{\nabla^2 a_2}{a_2} + Q_2' = 0 \tag{3.22}$$

Contrary to what might have been expected *a priori*, each one of these waves does not satisfy its own one-particle Schrödinger equation. On the other hand, the usual quantum mechanical description attributes, to this system, a behavior that follows as a result of the two-particle Schrödinger equation,

$$\begin{aligned} & i\hbar \frac{\partial \Psi(\mathbf{R}_1, \mathbf{R}_2, t)}{\partial t} = \\ & -\frac{\hbar^2}{2m_1} \nabla_1^2 \Psi(\mathbf{R}_1, \mathbf{R}_2, t) - \frac{\hbar^2}{2m_2} \nabla_2^2 \Psi(\mathbf{R}_1, \mathbf{R}_2, t) + V(\mathbf{R}_1, \mathbf{R}_2) \Psi(\mathbf{R}_1, \mathbf{R}_2, t) \end{aligned} \tag{3.23}$$

in configuration space. In the proposal of Andrade e Silva it is the inclusion of the appropriate quantum potentials $Q_1^{'}$ and $Q_2^{'}$ that will allow for the recovery of the configuration space two-particle Schrödinger equation above.

3.5.1 The interacting quantum potentials

Equations (19) to (22) above will give the behavior of the two interacting particles in 3D space, that is, the behavior of the two physical waves given by equations (17) and (18). The quantum potentials $Q_1^{'}$ and $Q_2^{'}$ depend on the variables $(\mathbf{r}, \mathbf{R}_1(t), \mathbf{R}_2(t); t)$ through both amplitudes a_1 and a_2, that is, Q_1 depends on a_1 and on a_2, and so does Q_2. These quantum potentials are non-local, i.e., they correspond to special interactions which are instantaneous at a distance, in physical space. The result arrived at by Andrade e Silva for the quantum potentials in physical 3D space was

$$Q_1^{'} = Q_2^{'} = -\frac{\hbar^2}{2m_1}\left(\frac{2(\nabla a_1 \cdot \nabla_1 a_2)}{a_1 a_2} + \frac{\nabla_1^2 a_2}{a_2}\right) - \frac{\hbar^2}{2m_2}\left(\frac{2(\nabla a_2 \cdot \nabla_2 a_1)}{a_2 a_1} + \frac{\nabla_2^2 a_1}{a_1}\right). \tag{3.24}$$

This is the sought for expression for the quantum potentials of interaction between the two particles (besides any classical interaction potential) that allows the required reduction to the usual Schrödinger equation for two particles in interaction, in configuration space, following the argument sketched below.

3.5.2 Recovering the Schrödinger equation in configuration space

The accepted two-particle Schrödinger equation, given by (23) above, evolves in the 6D configuration space $(\mathbf{R}_1, \mathbf{R}_2)$ of the system of distinct and interacting particles under consideration. Substituting now a solution of the form

$$\Psi(\mathbf{R}_1, \mathbf{R}_2; t) = f(\mathbf{R}_1, \mathbf{R}_2; t) e^{iS(\mathbf{R}_1, \mathbf{R}_2; t)/\hbar}, \tag{3.25}$$

in that equation, we obtain, as usual, the set of equations

$$\frac{\partial f^2}{\partial t} - \frac{1}{m_1}\nabla_1 \cdot (f^2 \nabla_1 S) - \frac{1}{m_2}\nabla_2 \cdot (f^2 \nabla_2 S) = 0,$$

$$\frac{\partial S}{\partial t} + \frac{1}{2m_1}(\nabla_1 S)^2 + \frac{1}{2m_2}(\nabla_2 S)^2 + \tag{3.26}$$

$$V(\mathbf{R}_1 - \mathbf{R}_2) - \frac{\hbar^2}{2m_1}\frac{\nabla_1^2 f}{f} - \frac{\hbar^2}{2m_2}\frac{\nabla_2^2 f}{f} = 0, \tag{3.27}$$

where the last two factors form the system quantum potential, $Q(\mathbf{R}_1, \mathbf{R}_2; t)$ in configuration space. The relationships between the two waves Θ_1 and Θ_2 in real 3D space and the system Ψ wave in configuration space are recovered by way of the correspondences

$$\begin{aligned} a_1(\mathbf{r}, \mathbf{R}_2; t) &\longrightarrow f_1(\mathbf{R}_1, \mathbf{R}_2; t),\ \varphi_1(\mathbf{r}, \mathbf{R}_2; t) \longrightarrow S_1(\mathbf{R}_1, \mathbf{R}_2; t) \\ a_2(\mathbf{R}_1, \mathbf{r}; t) &\longrightarrow f_2(\mathbf{R}_1, \mathbf{R}_2; t),\ \varphi_2(\mathbf{r}, \mathbf{R}_2; t) \longrightarrow S_2(\mathbf{R}_1, \mathbf{R}_2; t) \end{aligned} \tag{3.28}$$

and also

$$f_1 \times f_2 = f(\mathbf{R}_1, \mathbf{R}_2; t), \tag{3.29}$$

along with the conditions that the configuration space phase function S has to satisfy, namely $\nabla_i S = \nabla_i S_i = m_i \mathbf{v}_i$, with $i = 1, 2$ here, as well as the fundamental ones established in Andrade e Silva's thesis and also in [4].

The main result we intended to recall here is that it is possible to obtain, for systems of distinct and interacting particles in physical 3D space, a quantum description which associates each one of them with its own wave, this realistic picture having a well established correspondence with the usual description afforded by the Schrödinger equation in configuration space. This addresses partially the problem mentioned by Holland in [10], on the compatibility between the use of the concept of trajectory in associating an individual wave with each particle, and the no-trajectories description provided by the Schrödinger equation. It remains true, on the other hand, that the non-relativistic proposal here recalled is nonlocal, due to the instantaneous dependence of the "individual" quantum potentials on the coordinates of all the particles of the system. On this issue, it is no different from Bohm's quantum mechanics and from orthodox non-relativistic quantum mechanics.

Later, de Broglie [7] developed the initial arguments for a similar real space description of systems of particles of identical nature, both bosonic and fermionic. If successful, this research programme would restore a completely realistic interpretation of quantum systems in physical, three-dimensional space, albeit still with non-local quantum potentials.

3.6 The subquantum random medium

Another key ingredient considered in the thesis by Andrade e Silva, and also addressed by de Broglie, was the consideration of the existence of a sub-quantum physical medium, with an undefined energy content but capable of exchanging energy (and, presumably, momenta) with the particles. This consideration led

de Broglie to develop a "thermodynamics of the isolated particle" [11] and Croca to take advantage of the random interactions of this medium with the acrons to propose a general *principle of eurhytmy* according to which the acron follows a trajectory given on average by the intensity of the overall Θ wave, but nevertheless subject to random fluctuations due to this sub-quantum medium. According to Croca, the relative phases between the individual Θ waves associated with a system of two particles are what ultimately explains they being attracted or repelled from each other, as in the electromagnetic interaction. A simulation pretending to exemplify an attractive interaction between two acrons is shown in the figure below, in successive time frames, clockwise from the upper left frame. The last frame displays the final state of coalescence between the two acrons. It is important to stress that the trajectory of each acron is not deterministic, due to the sub-quantum medium, so the overall behavior is obtained on average.

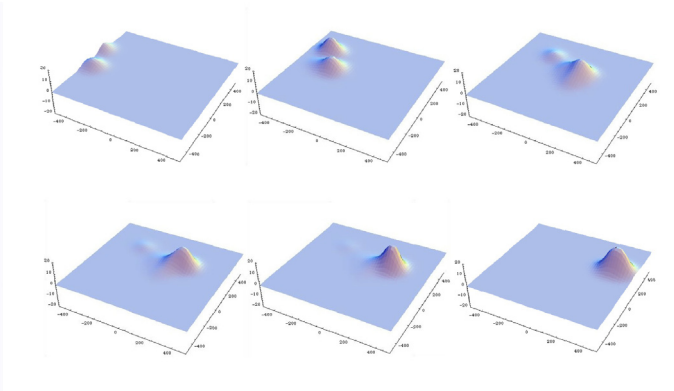


Figure 3.1: Two particles ("acrons") in interaction according to the principle of eurhythmy, leading to the final coalescence.

The introduction of the sub-quantum medium hypothesis was considered by de Broglie a fundamental ingredient for a proper understanding of quantum phenomena, to be duly incorporated in the double solution theory. After the previous work, by Andrade e Silva, de Broglie himself and others, on the description of systems of particles, and recognizing the limitation of the physical space description thus far achieved to systems of distinct particles, the obvious need of extending that type of description to systems of bosons and to systems of fermions was attempted, but still without addressing the question of non-locality. Specifically, de Broglie, in [7], began considering simple systems of two identical, spin-zero bosons, and also two identical spin-one half fermions.

3.7 More objections relative to realistic, local theories : EPR and Bell's theorem

An almost undisputed interpretation of the quantum world nowadays considers the existence of non-local correlations between some experimental measurements, the so-called *entanglement*, for example of the spin projections for two electrons in a singlet state, once allowed to fly apart a large distance. According to standard elementary quantum mechanics, the singlet state is represent by the linear combination

$$\mid 0,0\rangle = \frac{1}{\sqrt{2}}\left(\mid 1/2,+1/2\rangle_1 \mid 1/2,-1/2\rangle_2 - \mid 1/2,-1/2\rangle_1 \mid 1/2,+1/2\rangle_2\right)$$

in which the combined system is described by the state vector $\mid 0,0\rangle$ having a total spin eigenvalue of zero, as well as a null projection of total spin along any direction one may choose as the "z-axis". The linear combination on the rhs of the = signal specifies the two possible outcomes of the spin measurements for the two flying electrons, of spin 1/2 each : either one obtains a positive projection for electron 1 and negative projection for electron 2, or else a negative projection for electron 1 and positive projection for electron 2.

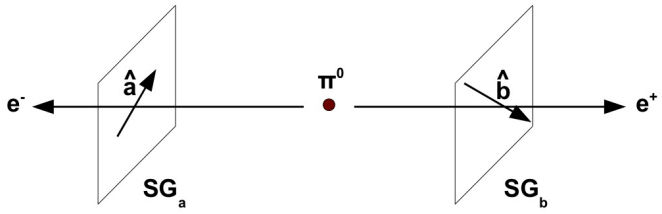
It is generally agreed that one can not claim that, in mid-flight, the two-electron system is already in one of the two possible combinations, either
$\mid 1/2,+1/2\rangle_1 \mid 1/2,-1/2\rangle_2$ or $\mid 1/2,-1/2\rangle_1 \mid 1/2,+1/2\rangle_2$. On the contrary, only the whole singlet state is present, and it is the state one has to attribute to the system until the measurement is finally performed. As a consequence of this assumption, there has to occur the celebrated "collapse" of the quantum state to one of the combinations above, which raises the question of how does one of the electrons "know" which direction its spin has to project onto, given that the spin of the other has been measured with a definite result, the two electrons being, by hypothesis, separated by a large distance. So large, in fact, that there would be no way for an exchange of information or some causal agent between the two electrons to be transmitted in time in order to insure that their respective measurements are compatible (if one is measured with spin "up", the other has to have the spin "down"). This mysterious correlation at a distance is a key ingredient in the defense of the concept of non-locality. The literature regarding these EPR correlations (and the "theorem" of Bell we will be referring to below) is enormous but, in keeping with the spirit of this Chapter, good references would be the book by the philosopher Tim Maudlin [12] and the collection edited by J. T. Cushing and E. McMullin [13].

3.7.1 The criterion of locality according to Bell

Bell ([14], Chap. 2) introduced a locality criterium expressing, in his view, the independence of the results of measurements in each wing of the experiment on the orientation of the Stern-Gerlach apparatus on the other wing. Accordingly, the possible results of a spin projection measurement along $\hat{a}$, say, would be $A(\hat{a} \mid \not{\hat{b}}, \lambda) = \pm 1$, and also $B(\hat{b} \mid \not{\hat{a}}, \lambda) = \pm 1$, in which $\{\lambda\}$ represents the set of hypothetical hidden variables The crossed letters in the arguments of both A and B above mean that the values of these functions do not depend on the orientation of the other Stern-Gerlach device. With this assumption, the expected value (i.e., the average computed after a long series of identical runs of the same experiment) for the product of the measured projections of both spins, each in its arm of the experimental set-up, will be given by

$$\langle A(\hat{a} \mid \lambda) B(\hat{b} \mid \lambda) \rangle = P(\hat{a}, \hat{b}) = \int A(\hat{a} \mid \lambda) B(\hat{b} \mid \lambda) \rho(\lambda) d\lambda \tag{3.30}$$

where $\rho(\lambda)$ represents an unknown probability distribution of a set of "hidden variables" $\{\lambda\}$ that could hypothetically keep the validity of locality in quantum correlations. As usual, this probability density would have to be non-negative and normalized to 1 ($\rho(\lambda) \geq 0$ and $\int \rho(\lambda) d\lambda = 1$). And since the spin projections for



electrons are dichotomic variables ($\pm 1 \times \hbar/2$), it is obvious that $B(\hat{b} \mid \lambda) = -A(\hat{b} \mid \lambda)$ and $[A(\hat{b} \mid \lambda)]^2 = +1 \times (\hbar/2)^2$.

Suppose then, as an example, that we choose three directions in space along each of which one can perform spin projection measurements, for each wing of the experiment. Starting from the basic hypothesis expressed in the computation of the average value for the product of projections measurements above, one can easily obtain inequalities such as

$$\mid P(\hat{a}, \hat{b}) - P(\hat{a}, \hat{c}) \mid \leq 1 + P(\hat{b}, \hat{c})$$

Let us choose, specifically, a situation in which $\hat{a}$ and $\hat{b}$ are orthogonal, whereas $\hat{c}$ is at 45° with both $\hat{a}$ and $\hat{b}$.

A simple quantum calculation (see, e.g., [15], Prob.4.44) gives the result

$$P(\hat{a}, \hat{b}) = -(\hbar^2/2) \times \cos(\hat{a}, \hat{b})$$

so that

$$P(\hat{a}, \hat{b}) = -(\hbar^2/2) \times \cos(90^{\text{o}}) = 0$$

and

$$P(\hat{a}, \hat{c}) = P(\hat{b}, \hat{c}) = -(\hbar^2/2) \times \cos(45^{\text{o}}) = -(\hbar^2/2) \times 0.707$$

Substituting these numerical results in the inequality above, on obtains $0.707 \leq 0.293$! Using *modus tollens*, one concludes that the initial assumptions are incompatible with quantum theory and of the experiments performed, and that physical reality in thus non-local.

3.7.2 A first principles critique

Jaynes [16] first exposed a fundamental assumption in Bell's reasoning which apparently goes counter a correct use of probability theory, specifically of the Bayes formula for conditional probabilities. In fact, when one deals with conditional events, the first consideration one can make is that this conditioning can be causal as well as logical. As a consequence, in conditional probabilities, the non-existence of a possible causal inference does not preclude the existence of a logical inference and, in the present context, what this implies is that, even admitting the impossibility of causal connections between the two wings of the experimental set-up, due to the large distance between the measuring apparatuses, there still remains the possibility of a logical relation between the measurement results, so that it is unwarranted to conclude that, in general, the result A is such that $A = A(\hat{a} \mid \hat{b}, \lambda)$, and also that $B = B(\hat{b} \mid \hat{a}, \lambda)$, as Bell did in his definition of locality. On the contrary, one should consider instead $A(\hat{a} \mid \hat{b}, \lambda) = \pm 1$, and also $B(\hat{b} \mid \hat{a}, \lambda) = \pm 1$, without thereby having to admit influences traveling instantaneously from one measuring station to the other.

According to basic probability theory (see, e.g., [17], Chapter 4, or [18], Chapter 5), the conditional probability of some event A occurring given that some other event H occurs, represented by the symbol $P(A|H)$, is given by the ratio $P(A|H) = P(AH)/P(H)$, or $P(AH) = P(A|H)P(H)$, in which $P(AH)$ means the probability of occurring both A and H (the conjunction of A and H). Now, supposing that event H is itself the conjunction of two events B and C, we may write $P(ABC) = P(A|BC)P(BC)$. But, by the same rule, $P(BC) = P(B|C)P(C)$ and

substituting we obtain $P(ABC) = P(A|BC)P(B|C)P(C)$ and not $P(ABC) = P(A|C)P(B|C)P(C)$.

However, it is this last equality which is in fact being implied when Bell starts his deduction by introducing $A(\hat{a} \mid \hat{b}, \lambda)$ and $B(\hat{b} \mid \hat{a}, \lambda)$, instead of $A(\hat{a} \mid \hat{b}, \lambda)$ and $B(\hat{b} \mid \hat{a}, \lambda)$, in the integral for the expectation value $P(\hat{a}, \hat{b})$ above.

Jaynes gives a simple example of a conditional probability dependent on a logical inference in a situation in which there can not occur a causal relationship. Consider the initial condition I in which a urn contains a total of N balls, in which M are red and $N - M$ are white, and with which R_i means "a red ball is obtained in the i-th extraction". Then $P(R_1 \mid I) = M/N$ and $P(R_2 \mid R_1, I) = (M-1)/(N-1)$, expressing a conditional probability with a causal dependence. However, since there are no causal relationships directed towards the past, Bell's criterium of causal independence would lead us to say that, for example, the probability of drawing a red ball in the first run, but with the knowledge that a red ball is drawn in the second run would be given by $P(R_1 \mid R_2, I) = P(R_1 \mid R_2 I) = P(R_1 \mid I) = M/N$, a conclusion which is wrong! This is particularly obvious when $M = 1$. In fact, the right result would be $P(R_1 \mid R_2, I) = P(R_2 \mid R_1, I) = (M-1)/(N-1)$. The upshot of this consideration is that Bell's locality criterium is too restrictive and, since it was essential in the deduction of his theorem, one has to conclude that this theorem does not have the general validity it is supposed to have. Consequently, the door becomes open for local, hidden variable theories capable of reproducing the experimental results of quantum mechanics.

A possible origin for this uncovered correlation would be common cause in the past of both daughter particles, this common cause being concealed in the description provided by quantum mechanics. In this regard, it is noteworthy that significant progress has been achieved in the last years, namely from the work of A. Kracklauer and of others. In fact, over a number of years, Kracklauer [19] has put forward arguments for the comprehensibility of the observed correlations in experiments with polarized photons by appealing basically to Malus's Law in Optics. Furthermore, this author goes as far as developing computer programs which reproduce the observed experimental results but assuming local realistic models (most easily obtainable from his site, [19]). In the same vein, H. de Raedt and co-workers ([20] and ([21]) developed local realistic models of the quantum correlations, reproducing the quantum mechanical results with entangled photon states and the corresponding idealized experiments.

In summary, the least one can say is that nonlocality as usually interpreted in the context of quantum correlations between entangled systems is far from being an incontestable fact of nature, and that the route remains open for an attempt

at reconstructing a quantum theory that accommodates both realism and locality.

3.8 Relativity and superluminal velocities

Up to now, in trying to extend the universe of possibilities for an exploration of the "eurhythmic physics" project, in the heels of de Broglie's approach but with a essential role attributed to nonlinearity, no mention has been made of relativistic considerations. However, one should keep in mind that the fundamental tenets of special relativity are not as ironclad as is usually supposed, not so much because of experimental difficulties, of course, but rather because of some degree of theoretical underdetermination from those experimental observations. The point we wish to emphasize here is the possibility of alternate formulation of the relativity principle regarding the validity of the coordinate transformations. One such example is provided by Selleri's "inertial transformations", which seem to respond to all the traditional experimental tests and, arguably, to better explain a few phenomena, such as the Sagnac effect. An added characteristic, of special interest here, would be the ability to allow for superluminal information exchanges, meaning that they can take place at speeds in excess of $c = 3\times10^8$ m/s. However, this possibility does not involve any causality paradox because a superluminal information exchange will not involve closed time-loops (see, among others, reference [22]).

It is perhaps worthwhile to give the main points behind this reformulation of special relativity considerations in the manner of Selleri's "weak relativity", which does not require that the laws of Physics be covariant among inertial reference systems, but only that the motion of the Earth through space to be undetectable. With this weaker requirement more transformations are possible and for reasons explained in [22] and elsewhere, one arrives, after selecting from other alternatives, at the inertial transformations given by

$$\Delta x = \gamma(\Delta x_0 - u\Delta t_0),\ \Delta y = \Delta y_0,\ \Delta z = \Delta z_0,\ \Delta t = \gamma^{-1}\Delta t_0 \tag{3.31}$$

with inverses given by

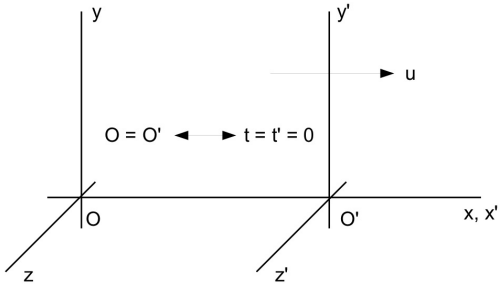
$$\Delta x_0 = \gamma^{-1}(\Delta x + \gamma^2 u\Delta t),\ \Delta y_0 = \Delta y,\ \Delta z_0 = \Delta z,\ \Delta t_0 = \gamma\Delta t, \tag{3.32}$$

and which had been already proposed by Tangherlini in his PhD thesis [23], where he calls them the *Absolute Lorentz Transformations*. Here, the subscript denotes that the corresponding coordinates are referred to a privileged reference frame, in which the velocity of light is isotropic and has value c. Note that, in particular,

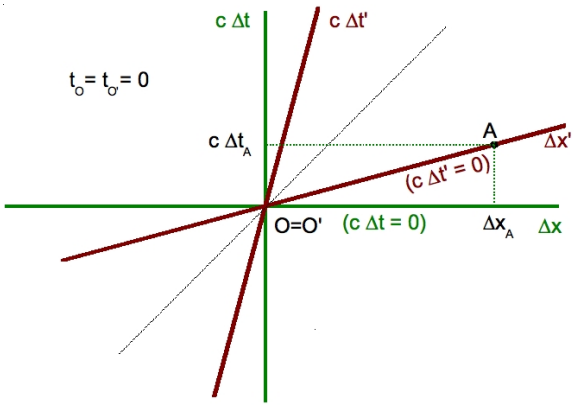
the time transformation restores absolute simultaneity, in contrast with the well-known consequence of the relativity of simultaneity deduced from the Lorentz transformations

$$\begin{aligned} c\Delta t^{'} &= \gamma(c\Delta t - \beta\Delta x),\ \Delta x^{'} = \gamma(\Delta x - \beta c\Delta t), \\ \Delta y^{'} &= \Delta y,\ \Delta z^{'} = \Delta z, \end{aligned} \tag{3.33}$$

where $\gamma = (1-\beta^2)^{-1/2}, \beta = u/c$, as usual. Both of these set of transformations refer to a system of axes as depicted in the figure below, one system moving with velocity u relative to the other, u having only a x component.

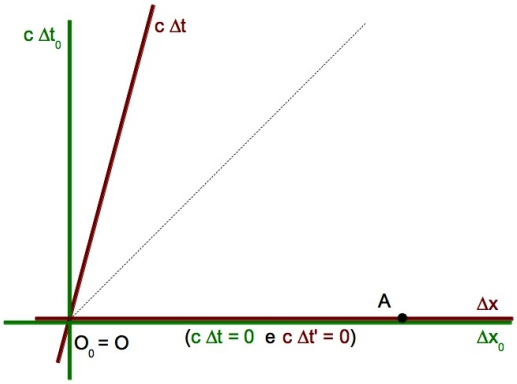


The space-time diagrams under these two sets of transformations clearly reflect their different imports. With the Lorentz transformations, one has the well known Minkowski diagram below, where event A is in the present of event O' and in the



future of event O (relativity of simultaneity: $\Delta t'_A = 0$ but $\Delta t_A > 0$).

On the other hand, for the inertial transformations the corresponding diagram would be the following, where the axes Δx_0 (*i.e.* $c\Delta t_0 = 0$) and Δx (*i.e.* $c\Delta t = 0$)



now coincide, making it clear that simultaneity is now absolute ($\Delta t_{0,A} = \Delta t_A = 0$).

Furthermore, superluminal velocities now do not imply causality paradoxes, as already mentioned [22]. And since there are known solutions of the wave equation $\nabla^2\Phi(x,y,z,t) = (1/c^2)\partial^2\Phi(x,y,z,t)/\partial t^2$ that, despite the $1/c^2$ factor are superluminal, one could perhaps envision a similar behavior in the definition of the quantum potential in such a way that, not only it could have the form of a d'Alembertian instead of a Laplacian, but also that the interaction speeds, although not infinite, could still be larger than c, allowing more freedom in the description of mutual interactions between quantum particles, and specifically in what concerns the establishment of the quantum statistics of similar particles and Bell-type correlations.

3.9 Conclusions

These notes pretend to highlight some minority proposals regarding the reality and the locality of physical phenomena at the quantum scale of events, with the hope of bringing about support for the revival of de Broglie's interpretation of quantum mechanics and to the novel proposals submitted by Croca. It is apparent that, contrary to common perception, there is still room for local, objective interpretations, even if proper physical descriptions and models have still to be developed. Key ingredients to be included in such future theory will be the description of any system of particles, be they distinct or of the same nature, by association with waves propagating in physical, 3D space; the inclusion of the sub-quantum

medium and a proper consideration of its effects on matter (waves and particles); and a definite clarification of the physical mechanisms responsible for the EPR correlations, given the limitations uncovered in the assumptions underlying Bell's theorem.

If we assign a physical identity to the wave, it will have to possess physical attributes, beginning with energy, no matter how small; but also linear and angular momenta of some sort. But if the wave also carries angular momentum, then the usual algebra of spin is erroneous, or at least incomplete. Not only the electrons in the singlet state carry spin angular momentum, but so must do the waves. Consequently, our algebraic description will have to take these into account. For example, one can consider that the singlet state represents rather an ensemble average and that the only one of the two-particle kets of the superposition exists in each run but associated, not by linear combination with the usual pair, but rather with the function representing the spin angular momentum of the involving wave such that the total spin angular momentum is zero, as in the original π-meson.

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Bibliography

[1] R. Feynman, R. Leighton and M. Sands, The Feynman Lectures on Physics, Vol.III, Chap.1; Addison-Wesley (1966).

[2] Yves Couder and Emmanuel Fort, Phys. Rev. Lett. **97**, 154101 (Oct 2006); Y. Couder, A. Boudaoud, S. Protière and E. Fort, EurophysicsNews, vol. 41, nº1, pp.14-18 (2010).

[3] P.J. Lewis, Life in Configuration Space, Brit. J. Phil. Sci **55**, 713-729 (2004).

[4] Louis de Broglie, Une Tentative d'Interprétation Causale et Non Linéaire de la Mécanique Ondulatoire (La Théorie de la Double Solution); Gauthier-Villars (1956).

[5] José R. Croca, Towards a Nonlinear Quantum Physics; World Scientific (2003).

[6] João E.F. Araújo *et al.*, A Causal and Local Interpretation of Experimental Realization of Wheeler's Delayed-choice Gedanken Experiment; Apeiron, vol. 16, no. 2 (April 2009).

[7] Louis de Broglie et João Andrade e Silva, La réinterprétation de la mécanique ondulatoire, vol.1; Gauthiers-Villars (1971).

[8] João Andrade e Silva, La Théorie des Systèmes de Particules Dans L'interpretation Causale de la Mécanique Ondulatoire, Thèse présenté a la Faculté des Sciences de Paris pour obtenir le grade de Docteur ès Sciences Physiques (Juin 1960).

[9] D. Bohm and B. J. Hiley, The Undivided Universe, an ontological interpretation of quantum theory; Routledge (1991).

[10] Peter R. Holland, the Quantum Theory of Motion, Cambridge University Press (1995).

[11] Louis de Broglie, La Thermodynamique da la particule isolée; Gauthier-Villars (1964).

[12] T. Maudlin, Quantum Non-locality and Relativity, 2nd ed.; Blackwell (2002).

[13] J. Cushing and E. McMullin, Eds., Philosophical Consequences of Quantum Theory; University of Notre Dame Press (1989).

[14] J. S. Bell, Speakable and Unspeakable in Quantum Mechanics; Cambridge University Press (1987).

[15] , D. J. Griffiths, Introduction to Quantum Mechanics; Prentice Hall, Inc (1995).

[16] E.T. Jaynes, Clearing Up Mysteries -The Original Goal, *in* Maximum Entropy and Bayesian Methods, J. Skilling (Ed.); Kluwer Academic Publishers (1989).

[17] S. Lipschutz, Theory and problems of Probability; Schaum/McGraw-Hill, New York (1968).

[18] W. Feller, An Introduction to Probability Theory and Its Applications; John Wiley & Sons, New York (1950).

[19] Several papers are available in his website, http://nonlocophysics.0catch.com/

[20] K. De Raedt it et al., A local realistic model for correlations of the singlet state, The European Physical Journal B bf 53, 139-142 (2006).

[21] K. De Raedt it et al., A computer program to simulate Einstein-Podolsky-Rosen-Bohm experiments with photons, Comp. Phys. Comm. **176**, 642-651 (2007).

[22] Franco Selleri, Lições de Relatividade, Edições Duarte Reis, Lisboa (2004).

[23] Frank Robert Tangherlini, The Velocity of Light in Uniformly Moving Frames, PhD dissertation, Stanford University (1958).

Chapter 4

On a possible contribution of transfinite mathematics towards eurhythmy

Gildo Magalhães
University of São Paulo, Brazil
(gildomsantos@hotmail.com)

4.1 Some epistemological considerations

Knowledge never achieves completion. Any system of theories, however excellent, ends by generating anomalies and paradoxes. This statement is valid for philosophical systems, scientific theories or other forms of investigative knowledge. If one takes, for the sake of argument, the history of physics, there are many examples to illustrate the point, such as the Ptolemaic geocentric system, or Newton's mechanics, or the orthodox quantum theory. There is no methodology to create axioms and rules that remain forever valid, therefore it is capital that the history of science be concerned with controversies that surround this knowledge, including the socio-cultural environment where these axioms originated. From the epistemological viewpoint, it is useful to exploit how the reactions to the controversies were, how they were judged at the time when different hypotheses, theories and experiments arose – as well as how they are historically and scientifically evaluated in the present.

On the other hand, nature does not function arbitrarily, rather it is open to our

rationality, and it is precisely this feature that allows us to know it, in better and better approximations. That nature is not arbitrary can be exemplified also in modern mathematical applications, such as the theory of chaos: natural processes which are seemingly random, in a vast number of cases show themselves to possess a hidden regularity, which was inaccessible at first view. It is thus reasonable to assume that there is always progress in knowledge, even though we face the contingency of creating new theories from time to time. There is also an attenuating factor in this process of transformation of the scientific body: even if dogmas from the prevailing scientific canon are changed, usually a new theory accepts as a valid limit case the old theory. So, there is no abrupt revolution in the short term, but gradual reforms. Even though many philosophers of science maintain that no comparison is possible between paradigms that are incommensurable, it is doubtful whether the two systems really do not converse with each other. Old and new controversies will intermingle and contribute towards an epistemological deepening and mutual better understanding.

The above considerations hinge on our disagreement with the opposition, sometimes in radical tones, between realism and idealism, when the latter term is taken as synonymous of Plato's concept of ideas. Every theory intended to explain the world is, in principle, a model, i.e. a representation of reality. Model building allows some forecasts, when the model is really good; historically speaking, explanatory models replace each other, but as noted above, in general something is retained out of the preceding models, originating a succession of more or less entangled models, permeating the advancement of knowledge. In the so-called Platonic world of ideas, the truth exists as well as the idea of truth – we may have limited access to this true world, while our models somehow probe such truth, though always in an incomplete way. In the well-known myth of the cave, Plato exploits the approximate discovery of the true idea, and his allegory adjusts well to even the most realist theories – always in a provisory form – that science adopts.

From this vantage point, we add our opinion that the history of the sciences has quite often corroborated that, in particular, mathematics is rooted in the activities of observing and interpreting reality. Accordingly, mathematics somehow does discover what already exists in the universe, even when theories are apparently invented out of the blue. Although the mathematical science has and fully uses its freedom to propose hypotheses and axioms, possibly more independently than in other sciences, it is remarkable that even those theories that appear to be most abstract and devoid of experience, sooner or later such theories end up as practical applications in natural sciences like physics, chemistry, biology or other forms of knowledge.

4.2 Cantor's theory of transfinites

We will now here advance some reflections involving on one hand the recent proposals relative to eurhythmy made by the Lisbon Group [CROCA: 2010][6], and on the other hand a topic which has already stirred much horror among the mathematicians: the discoveries about infinity by Georg Cantor (1845 – 1918). What is to be investigated is whether also in the case of infinities, there can be some application to this newborn theory of physics. We shall proceed very carefully, since we do not have sufficient elements to make it operational.

Initially we recall that Cantor in his 1883 *Grundlagen (Foundations of a general theory of manifolds*, Note to Section 1) [3] justifies his resource to different infinities by quoting Plato's dialogue *Philebus or the Highest Good* [16]. There is in this dialogue an interesting passage (16 b,c,d) that bears upon our subject; let us hear Plato speak through Socrates:

> *... there is not, and cannot be, a more attractive method than that to which I have always been devoted, though often in the past it has eluded me so that I was left desolate and helpless... It is a method quite easy to indicate, but very far from easy to employ. It is indeed the instrument through which every discovery ever made in the sphere of the arts and sciences has been brought to light... The men of old, who were better than ourselves and dwelt nearer the gods, passed on this gift in the form of a saying. All things, so it ran, that are ever said to be consist of a one and a many, and have in their nature a conjunction of limitedness and unlimitedness.*

The elaboration of this thought in number theory was Cantorian mathematics' main contribution to science. The departure point that enabled Cantor to arrive at the transfinite, besides the already-mentioned Platonic inspiration, seems to have been St. Augustine, who in *The City of God* (Book 12, chap. 19) [1] characterized the whole series of integer numbers as a real infinity, and not just a potential, or virtual one, as demanded by ancient philosophy, especially Aristotelianism.

Georg Cantor studied philosophy in Zurich, and then mathematics with Karl Weierstrass (1815 – 1897) in Berlin, where he finished his doctorate in 1867. Until 1878 his works dealt with classical mathematics, and after that, he worked on the theory of infinite numbers. His original results led him to be severely attacked by orthodox mathematicians orchestrated by his great personal enemy, Leopold Kronecker (1821 – 1897), who defamed him and kept him from being published in prestigious mathematics journals, as well as tried by all means that he failed to get a university chair. Cantor's isolation due to such persecution plunged him in peri-

ods of depression, paranoia and nervous breakdown, but which he was initially able to overcome, going back to writing his major work, *Contributions to the founding of a theory of transfinite numbers (1895 –1897)* [4]. Afterwards he suffered again several other mental crises, and ended up interned in a psychiatric hospital, where he died. Recognition of his work was late, and it still suffers attacks today – even though the famous mathematician David Hilbert (1862 – 1943) stated (1926) that "no one can drive us out of the Paradise created for us by Cantor".

Cantor calls a set (German "Mannigfaltigkeit", or "manifold", multiplicity) everything that is complete and determinate, even if infinite. A set constitutes a collection of objects of sensation, intuition or thought, and for him such a collection is related to the Platonic "idea". Besides finding inspiration in Plato, and in the philosopher and theologian Augustine, he carefully studied Thomas Aquinas and Nicholas of Cusa, besides Giordano Bruno, who all also reflected on the matter of infinity. Basically, in his intellectual journey he took sides against Aristotle, for whom real infinity does not exist, and everything perceived by us is finite and limited, and from our limited sense perception derives the mind's finitude.

We know that in physics something as a light wave is not really infinite in time or space, though considering it as infinite might help disclose its approximate behavior, an approximation which is useful under certain circumstances. Indeed, only recently, by substituting the infinite waves which have been used since the 19th century in Fourier's analysis by finite wavelets, as did the leader of Lisbon Group, José Croca, it was possible to create a truly causal theory for quantum phenomena which has revealed itself consistent. Are there infinite systems in our common practice? Even if we object to this on physical grounds, adopting the Aristotelian standpoint which admits of the sense limits imposed on space and time, we have not yet been able to verify whether real space is infinite or not, we can at most admit that "infinite" may stand for an approximation of an unreachable space finitude. That is also assumed by the new hyperphysis, as it imagines as meaningful, at least approximately, to describe an akron as having infinite intensity – this is the visitation hypotheses [CROCA: 2010, p. 20][6], to compare it with its accompanying wave.

The same discomfort with infinities revealed in physics praxis has surrounded mathematical thought. Reformulating the question, is there a contradiction in assuming infinite sets to exist, mathematically speaking? Conceptually, the answer is negative: at least for Cantor and his adepts, we are entitled to consider infinities as an exact mathematical description. Richard Dedekind (1831 – 1916), Cantor's close friend and correspondent, defined (*Essays on number theory*, 1888) as infinite the system which is similar to a part of itself, and then proved that there exist infinite systems by using the set S made up of the totality of things that can be

object of his own thoughts. If s is an element of S, then the new thought s' that s can be an object of thought is itself an element of S. If we regard this as a transform $\Phi(s)$ of the element s, the transformation Φ has the property that the transform is part of S; certainly S' is part of S, there are elements in S (e.g. one's own ego) which are different from such thought s', and therefore are not contained in S'.

The capacity of thought to think itself was used by Cantor in his second major publication on the transfinite, *Contributions to the founding of the theory of transfinite numbers* (1895 –1897). In this one, he started with the set of natural numbers $1, 2, 3, 4, \ldots$, which can be put in a one-to-one (biunivocal) relationship with the set of even numbers $2, 4, 6, 8, \ldots$, even though the latter is contained in the former. Sets will be "equivalent" whenever one of them or part of it is thus related to the whole of the other set. This property is in turn connected with the linearization of the counting process, for a linear whole contains its parts, yet the attempt to linearize infinite sets confronts us with a paradox: the whole is equivalent to its parts, and this is the property that defines an infinite set, or as Cantor called it, a transfinite. Linearization can extend, therefore, the properties of a set until infinity, but in a fixed mode, which does not change the process in itself.

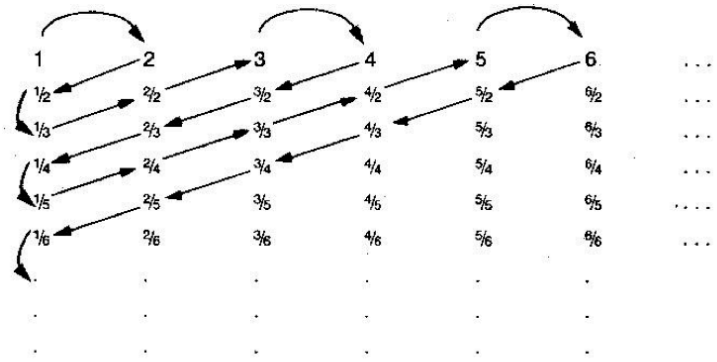
Incidentally, these properties of linearization reappeared more recently when the fractal theory originated in mathematics: through Mandelbrot sets geometrical figures are generated, so that when these are enlarged they are seen to reproduce the initial configuration. These fractals are also infinite sets, and they verify the statement that the whole is equivalent to a part of it. Once more mathematics and reality are combined, since fractals are the best description for a series of physical processes: the anatomy of biological networks, such as plant vessels or the nervous system; the geographical profile of the sea coastal zones; and many other practical applications.

In a letter (1885), Cantor says that the series $1, 2, 3, ...$ is a variable magnitude, which may increase without limits – it is a potential infinity. He then defined the "power" (Mächtigkeit), or "cardinality", of a set as a number that denotes a transformation measure: how many orders of abstraction differentiate a given set from another one. This was the consequence of Cantor's perception that the infinite natural numbers could be arranged in a one-to-one relation, not only with the infinite even or odd numbers, but also with the infinite fractions (rational numbers), containing integers both in the numerator and denominator. His reasoning was according to the following figure:

The demonstration by Cantor that infinite sets of rational numbers are countable and have the same power as the natural numbers is ingenious: in the preceding figure fractions are arranged in a matrix, such that the first line has all fractions $n/1$ (n are the natural numbers). The second line has all fractions $n/2$, the third one $n/3$, and so successively. A diagonalization process is then applied, starting with fraction $1/1$, then going to $1/2, 1/3, 2/2, 3/1$, etc. In the n-th step "n" elements have been picked, so that all possible fractions will be included. The result obtained is a one-to-one correspondence among the natural numbers of the first line and all possible existing fractions, which are therefore countable, even though there is an infinite number of them, as between 1 and 2, for example. There is also a one-to-one correspondence between the set of natural (or countable) numbers and many others, as the set of all square numbers, or also the set of all prime numbers.

However, since Ancient Greece we have known that there are numbers such as the square root of 2, which cannot be expressed by fractions, the so-called irrational numbers. All constructible numbers (i.e. those that can be constructed with ruler and compass) are algebraic – they are roots of an equation of the form $a_n x^n + a_{n-1} x^{n-1} + \ldots + a_1 x + a_0 = 0$, where the coefficients are rationals. Cantor was surprised to discover that the algebraic irrational numbers, as $\sqrt{2}$ (which can be constructed as the diagonal of a square whose side is equal to 1), though there is an infinite number of them, could also be put in a one-to-one correspondence with natural numbers. Cantor called all these different types of numbers "countable", pointing out that they all have the same generative principle, i.e. the same power: they can all be linearly ordered, and correspond to definite points on a line, where they can be counted using the sequence of natural numbers.

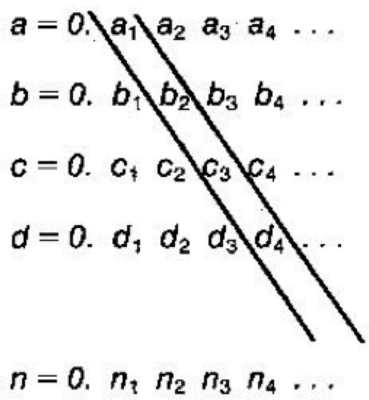
The sets of numbers described so far make the line be infinitely dense. However, there are "gaps", since we left out the transcendental, or non-algebraic, numbers



such as π, the ratio between the circumference and its diameter[1] . That was the key for Cantor to realize that there is more than one type (or power) of transfinite set. As in the case of $\sqrt{2}$, the number π cannot be expressed as a fraction, but more importantly, it cannot be constructed with ruler and compass, what would be possible if it could be defined through an equation similar to the one that defines the diagonal of a square; π can be given as the sum of an infinite series, which is in practice an approximation, but not an exact expression, thus it cannot be physically constructed. Therefore π is irreducible, it is something primitive and given, and though it is a very concrete relation between two values, the circumference and its diameter, it can be only idealized in the Platonic sense.

Taking into account the transcendental numbers, the infinity of countable numbers is not any more sufficient to hold the new set. The power of a set of real numbers, including the transcendental ones, is greater than the power of countable numbers, and so Cantor called the first one "non-countable". The first infinity is countable and has a cardinal number he called $\aleph_0$ (aleph-0), while the second infinity is non countable, with a cardinality of $\aleph_1$ (aleph-1).

To demonstrate that real numbers are non-countable, Cantor used a different process of diagonalization, as in the following figure:



The demonstration that the real number set has a higher power is through *reductio ad absurdum*, by admitting there is a way to order them (i.e. to put them in a one-to-one correspondence with countable numbers), such as in the figure above. Cantor chose to represent real numbers as an infinite series of decimals, periodic or

[1]The proof that π is not algebraic was given only in 1882 by Ferdinand von Lindemann, thus ending the ages-long controversy historically known as "squaring the circle". Modern algebra approaches the general concept of numbers in a more abstract way using Galois groups.

not. Any real number is thus expressed with an integer part, followed by decimals – for example, $2 = 2.000000...$; $\pi = 3.141592...$; $\sqrt{2} = 1.414286...$ in the figure we suppose that the infinite list contains in principle all real numbers (to simplify, the integer part was chosen as zero). The new diagonalization devised by Cantor is intended to construct a new number, starting with the integer part. For a new first decimal, one chooses any digit different from a_1; for the second one, any digit different from b_2; and so on. The new number is indeed different from any other in the infinite list: it is altogether different from the first one because its first decimal is different; it is also different from the second one in the list, etc. If the new number is added onto the original list, we apply the same procedure and create a newer number, which is not present in the modified list. This means that there is no counting process that passes through all real numbers, contrary to the initial supposition.

It is surprising that the power of the set of points on so dense a line associated to the real numbers is the same as any subset of the line, as for example in the interval from zero to one. It is also equal to the power of points in any dimension, as in the unit area or unit volume. The process of formation of non-countable infinities is thus non linear.

Extending his reasoning beyond these concepts, Cantor concluded that it is possible to create a transfinite number next to aleph-one, i.e. aleph-two, and in fact transfinite such numbers, so that there is no transfinite greater than all others. Each one will be non-countable and characterized by a power; as seen before, integers, rational and irrational numbers have a power equal to zero, and the real numbers a power equal to one. For successively greater transfinite numbers, such that $A < B < C...$, Cantor demonstrated that $2^A = B$, $2^B = C$, etc

The cardinality is associated to the size of a set, that is, the number of elements it contains. The arithmetic of transfinite cardinal numbers follows some rules which are different from those of finite numbers, such as:

i) If a, b are cardinals, with $b \geq a$, and at least one of them (b) is infinite, then $a + b = b + a = a \cdot b = b \cdot a = b$.

ii) $a < 2^a$, a being finite or infinite.

For Cantor what matters is the generating principle of the new number classes, and each one cannot be generated from a simple linear increase of the preceding series, contrary to how we can, say, form an integer greater than any other one,

just by adding one unit, i.e. through counting.

There is still an unsolved problem in the history of transfinite numbers: the continuum – the set C of all real numbers is it part of aleph-one, or is it exactly equal to aleph-one? As stated before, by mapping real numbers onto an infinitely long line, one can demonstrate that the set of these numbers contains as many elements as there are in a segment of the line. This makes any line section infinitely dense and with no gaps: between any two real numbers, there is an infinity (of cardinality aleph-one) of real numbers. It is exactly the presence of the transcendental numbers which fills up the gaps. The "continuum hypothesis" is that the real number set has a cardinality of aleph-one, as Cantor sustained a number of times, but there is no proof of that. In 1938, Kurt Gödel (1906 – 78) proved that it was not possible to demonstrate the falsehood of the continuum hypothesis, and 25 years later Paul Cohen (1934 – 2007) proved also the reciprocal, i.e. it cannot be demonstrated to be true by using the axioms of set theory. Cohen still conjectured (*Set theory and the continuum hypothesis*, 1966) that the continuum would in fact be much denser, and would have a cardinality greater than any aleph, its generation being a totally different process than generally assumed – but that remains an open question.

Besides what has already been presented, Cantor worked with the concept of ordinality. A set has an ordinal number which corresponds to the position this set occupies in a list whose first position is that of the sets with just one element, the second position is that of the sets with two elements, and so forth. In the case of finite sets, cardinality and ordinality coincide. For infinite sets, their cardinal does not coincide with the ordinal, and there are infinite distinct ordinals (positions) for the same cardinal.

A new arithmetic for transfinite ordinal numbers arises then, with peculiar commutative, associative, and distributive properties, such as:

- $\alpha + \beta \neq \beta + \alpha; \alpha \cdot \beta \neq \beta \cdot \alpha$
- $(\alpha + \beta) + \gamma = \alpha + (\beta + \gamma), (\alpha \cdot \beta) \cdot \gamma = \alpha \cdot (\beta \cdot \gamma)$
- $\alpha \cdot (\beta + \gamma) = \alpha \cdot \beta + \beta \cdot \gamma$

If ω designates the ordinal number associated to the cardinal aleph-zero (countable numbers), one can demonstrate that $\omega + \omega = \omega$, and also $\omega \cdot \omega = \omega$.

4.3 Transfinites and human reason

About the ancient "problem of the one and the many", Cantor wrote to his friend Richard Dedekind about a contradiction if the multiple set is considered a member of the original "one" set. It is the famous paradox identified by Cantor himself, and later by the end of the 19th century discussed by the mathematician Cesare Burali-Forti (1861 – 1931), better known in the following version under the name of [Bertrand] Russel´s (1872 – 1970) antinomy: the barber of a village where no man shaves himself, and where every man is shaved only by this barber, can he shave himself? This reminds of the type of contradiction that arises of statements like: "this sentence is false". That is not, however, what Cantor considers valid in his formulation of set theory, for him this mental trap can be avoided by considering that a multiplicity, even when infinite, must be thought of as something wholly new and different from its countable elements, and can only be thus adequately conceived.

The very human mind, or world of thoughts (Gedankenwelt), was the object of a mathematical demonstration offered to Cantor by Dedekind, who considered such a set as an infinite multiplicity (manifold) with all infinite alephs that could be conceived. This point is extremely important: human mind, in spite of its biological limitations - along the line pointed out by Aristotle in relation to potential infinity – has an infinite possibility to form new classes of transfinite numbers with ordered growing powers. This mental exercise is key to mathematically formulating human creativity, which manifests itself in all areas of knowledge, including artistic creation. Aleph-zero would then be a first "mode of thinking", whereas aleph-one is a "mode of thinking the mode of thinking". It is as if each transfinite were a quantum, or a monad: it is a unity that may have parts, but it behaves as a new being, which is more than the sum of its parts - it is not linearly reducible.

In the context that Cantor discussed these notions there was also a theological problem, which defied his religious faith, although he was not affiliated to any church. Contrary to what may be thought nowadays, when it is common to push religious considerations entirely out of the scientific practice, it was exactly theology that helped Cantor solve some formal problems of transfinite mathematics. For him, it became clear that the transfinite of real numbers is a creation belonging to this world and can be intelligible to mankind, whereas an "absolute infinity" lies in Plato's world of ideas, or is, theologically speaking, God's uncreated and exclusive attribute. This led him to admit that man can face real infinities, and thus the unity of the multiple, without contradicting himself – a multiplicity is consistent with a "set" provided of its own individuality. This power to be himself a creator allows man to solve problems by further creating new problems. If there were no

problems to solve, neither inconsistencies that arose out of them, man would have no need for creativity, all of which is pertinent to the world of thoughts, as Cantor and Dedekind perceived.

The above theological argument has an important mathematical and scientific implication: there can be no complete axiomatic system, since sooner or later new axioms have to be created to solve the ensuing paradoxes of incompleteness. Such a feature fully agrees with reality, as a careful study of the history of physics shows, or moreover the history of any science demonstrates. Truth becomes a pathway to be uncovered and followed, not a final goal: the ultimate transfinite is not within the human reach, the absolute infinity can only be intuited but never attained. The ultimate truth is not human, it belongs to the absolute – whether it is a "God" as Cantor believed, or the universe itself, in a natural version. This is the trail of advancement of knowledge, which keeps us from embracing nothingness, the empty – as novelist Michael Ende well characterized in his fable (for children and adults alike) *The Neverending Story*, where he portrays how the worst threat for mankind would be the loss of creativity, leading into the advancement of nothingness – the destruction of fantasy entails the substitution of the universe for a non-universe.

The attempts to transform the whole of mathematics in just logic and symbolism, divorced from reality, received an impulse with the formalization undertaken by Bertrand Russell and Alfred Whitehead at the beginning of the 20th century, in their work *Principia Mathematica*. The mathematician Kurt Gödel (1906 – 1978) counter-attacked this philosophical trend at the beginning of the 1930s, when he published his essay "On formally undecidable propositions of *Principia Mathematica* and related systems". He demonstrated therein that any formal system, to be free of contradiction (or "consistent") must be incomplete, i.e. open to the generation of new laws and axioms. In 1964, Gödel expanded that initial scope to oppose Alan Turing's (1912 – 54) work on cybernetics, including his pretension to build "artificial intelligence" through a computer.

The general definition of algorithm advanced by Turing is well known. It is associated with the so-called "Turing machine" (1936), a sequential device which processes a few simple operations in a recursive way (implying a "mechanical", countable process), just like the future digital computers would do. However, using a Turing machine is feasible exactly only for countable procedures, which accept a precise and closed definition to establish a calculation, an algorithm. When it is applied to problems such as, for example, defining real transcendental numbers, the machine eventually does not know whether to stop or continue its processing, for there is no algorithm to define such numbers, or any non-countable infinity. The validation of the calculation in this case must be accomplished through external

means, as Gödel demonstrated, based on Cantor's previous work.

In other words, what distinguishes the functioning of the human mind from any computer language is that we are open to accept contradictions in the form of ambiguities, anomalies, paradoxes, metaphors, etc, which we solve and incorporate, whereas formal systems are closed and exclude such contradictions and inconsistencies, under the risk of not being able to proceed – and any additional attempt to provide a rule for the computer to deal with ambiguities will be short-lived, as it will stop again at a further contradiction.

As a matter of fact, the advancement of knowledge, which is more readily verified in the case of natural sciences, has been possible through the constant intrusion of anomalies, as shown in the history of science. Such anomalies are like non-linearities in a process which up to a certain point is well conducted and well described by a linear approximation. Though this approximation can be quite useful within certain conditions, it may however reveal itself fallacious when extended beyond those limits. The non-linear may even be linearized and provide satisfactory answers, yet one must be ready at some point to meet paradoxes derived from the adopted approximation.

4.4 The quantum substrate and the transfinite

A new question arises: if the very human mind works with discontinuities (quanta) in the process of creation, do the natural processes in the universe we inhabit also share the essence of distinct parts, which in the end form transfinite sets? For Cantor the answer was undoubtedly yes, both the continuous and discontinuous, the transfinite and the finite are two aspects of a unitary whole, to which we also belong. To exemplify the matter, would the so-called "space-time continuum", as popularized by the relativity theory, be a "stratified" continuum, yet a non-linear one? If it were so, in hyperphysis when dealing in space-time with the subquantum level, would the substrate allow for linearization, and appear like some traditional substrate, as reality often seems to be linear in a larger scale?

The answer cannot be a simple one. Linearization is, at most, a particular case, and it is liable to introduce distortions, which can be more or less relevant. Even in the mathematical domain, this is an interesting possibility, when one considers for example the class of functions that Karl Weierstrass (1815 – 1897) demonstrated to exist: continuous functions which are nowhere differentiable. Such a function cannot be linearized, not even in an infinitely small neighborhood of any of its points. The property of being continuous and non differentiable occurs when

the function's graph shows edges or when it leaps, or also if it neither converges nor is defined. How does this impact on physical processes at the subquantum level?

Very peculiar properties of the subquantum medium were assumed as hypotheses in hyperphysis. The stronger hypothesis is that, consonant with the principle of eurhythmy, the organization of the subquantum medium that we call an akron (e.g. an electron) has a kind of sensory, its "theta wave" ("empty wave", or "pilot wave", a concept first introduced by Louis de Broglie in 1927), with which the akron "feels" its external world. This would be a special type of sensor, whereby the eurhythmy property causes the akron to move along the direction where the intensity of the theta wave is greater, to preserve its existence, which is in turn what directly or indirectly we can observe. In spite of its peculiar appearance and the "sensor" metaphor, which could be considered Aristotelian and more appropriate for biology than physics, the principle of eurhythmy was able to be successfully applied to explain well-known natural phenomena, such as the principle of Fermat (minimum time for light propagation in different media), and Snell's law for light refraction, or more generally the principle of least action (Maupertuis and others), all resulting from the greater efficiency and harmony associated with the cited eurhythmical property.

In the hyperphysis associated with akrons and theta waves, the akron is "generated" or "emerges" out of the subquantum medium, and besides possessing an infinitely larger intensity, it has a longer mean lifetime, compared to its theta wave. Moving at its own velocity, the akron's mother-wave tends to disappear, returning the wave's energy to the subquantum medium. For the theta wave to persist, it must be regularly "revisited" by the akron (the "visitation hypothesis" mentioned before), or else the akron is decoupled from its mother-wave and will generate new theta waves as it moves along. The akron supposedly does not lose energy when moving, and it behaves approximately as an infinite energy reservoir, capable of generating an infinity of theta waves. To derive the expression for the intensity of the theta wave as "seen" by an akron, it is assumed that if it meets another theta wave whose intensity is much greater than its mother-wave, it will "feel" just the energy of the stronger wave. Reciprocally, if the mother-wave is stronger, the akron will continue following the mother- wave.

In an analogous manner one could suppose that a function describing the internal structure of an akron at the subquantum level should not be linearizable below a certain minimum distance from it, i.e. non-linearity becomes an indicative of the existence of internal structures, which may also explain its movement in the substratum. The energy of the pair is practically concentrated in the akron, but it is the theta wave that guides it, its energy is relatively insignificant (an estimate

is that it is 10^{-54} times smaller). How can such small energy, distributed in an undulatory manner, help guide the akron to where its intensity is a maximum, unless there is an internal structure to the akron?

We do not possess a physical answer in the model for the question, but a formal way of putting it would be to ascribe to the akron the mathematical property of infinite cardinality, letting the akron be associated with some aleph, so that its energy content follows the infinite composition of transfinite intensities. Of course, we do not intend anything but an approximate description for certain subquantum conditions, where for the akron's intensity we would have something like $\aleph + \aleph = \aleph$. This all being just conjectures, we may as well suppose that the interactions among akrons also follow transfinite arithmetic, using either cardinal or ordinal numbers. Also for any theta wave, it may be considered as composed by a mother theta wave and other theta waves, forming a packet of wavelets.

How can we describe the resultant of several theta waves and their akrons that interact mutually, given that each interaction is in itself non linear? The mathematical difficulty that hyperphysis has encountered first led to a prudent traditional solution, which is the return to linear approximation, forcibly acknowledging that the validity of the result is a limited one. In this way several hypotheses to determine the akron's velocity were studied, by varying the intensity of the theta wave from which the akron emerges, the type of medium, and its initial velocity. Maybe by using transfinite mathematics one could obtain an applicable tool, with the advantage that it would not have the philosophical flaws that linear approximations carry, and considering some similarities in non-linearity between Cantor's theory and the properties of hyperphysis. In particular, if the akron has an infinite intensity a and the theta wave a finite intensity b, we obtain $a + b = b + a = a \cdot b = b \cdot a = a$.

It is as if we said that the principle of eurhythmy is a manifestation of a kind of interaction resulting of infinite intensities, which lead to the predominance of new infinities. Though the description provided is only barely qualitative, the reasons for the parallel between transfinite mathematics and hyperphysis phenomena are due to considerations like those recapitulated below:

- Real infinity is something constant, it does not change by addition or subtraction of set elements, or to say it in different words, the whole is similar to a part of itself. By reproducing its parts, the whole is equivalent to its parts, and this property defines what an infinite set is. Likewise, the set formed by at least an akron and its theta wave seems to display a similar property.
- Linearization may infinitely extend properties of a countable set, but it does so in a fixed manner which does not alter the process itself. On the other

hand, the process of infinity formation is a non linear one. Each transfinite is a unit, even if it has parts, it behaves as a new being which is more than just the sum of its parts. In a totally general way, nature does not seem fit for an exact linearization of its processes, which fact becomes evident when a linear description of a phenomenon breaks down at a certain point. This is exactly the case of quantum physics, where linearization is intimately coupled with a non causal description of phenomena.

- What is supposed to happen in the vicinity of an akron at the subquantum level has some analogy with the behavior of continuous functions which are neither nowhere differentiable nor linearizable in an arbritrarily small neighborhood.

Finally we should note that hyperphysis faces at one point the same problem that has confronted quantum theories up to now, that is, how to deal with infinite values which probably are a result of ignoring the internal structure of entities. For example, in classic theory when one considers the electron radius to be practically zero, then its self- energy tends to infinity – as in the case of several other entities that are approximately considered as "point particles". To cope with this problem, quantum theory introduced the renormalization concept, which corresponds grossly to subtracting an infinite value from another infinite one, under certain conditions, leaving a finite result.

The infinite values might however have a different meaning, one that we don't know yet how to interpret. A first clue is that infinities may indicate that the adopted approximation of the model is no more usable, i.e. we have reached a scale where a significant action of an internal structure comes into play. If we insist on ignoring the structure, we will meet with infinite values, and knowledge will only advance when there is courage enough to pursue that internal morphology. The proposal advanced in 1985 by Winston Bostick (1916 – 1991) [2] for a "chayah" (Hebraic for "living") still deserves to be remembered. Such "living" electron has a filamentary structure akin to the fusion plasma vortices, both those produced in laboratories and the natural ones observed in stars. It is possible that at such scale there is enormous energy liberation – similar to what nuclear energy represented in the past when one still assumed the nucleus to have a structure of only protons and neutrons, and conversion of matter into energy in the processes of nuclear fission and fusion showed energy levels much above those known at the time. Analogously the subquantum medium structure may show unsuspected energy magnitudes.

Secondly, from the formal point of view, the mathematics now used in the renormalization procedure may not be adequate, as it may falsify the behavior of func-

tions whose value is so great that we consider them to be infinite. Conceptually, we may be doing something equivalent to a false infinity statement, such as $\omega - \omega = 0$ (or some other finite value), instead of $\omega - \omega = \omega$, i.e. renormalization may falsely avoid unavoidable infinities, which are ultimately evidenced. Renormalization would then be no more than the reintroduction of linearity in a process where the infinities are there to emphasize the non-linearity of a phenomenon. Will hyperphysis avoid this procedure?

We leave these questions in the air, as they result from some still very hypothetical thoughts, to those willing to work with hyperphysis and eurhythmy, and not satisfied with the mathematical foundations for this work.

Bibliography

[1] Augustine, *St. City of God*. New York: Image Books, 1958

[2] Bostick, Winston. "The morphology of the electron". *International Journal of Fusion Energy*. Vol. 3, nº 1, January 1985, p. 9-52

[3] Cantor, Georg. "Foundations of a general theory of manifolds". (Orig. 1883) *Campaigner*, vol. 9, nº 1-2, January-February 1976, p. 69-97

[4] Cantor, Georg. *Contributions to the founding of the theory of transfinite numbers*. (Orig. 1895 e 1897). New York: Dover, 1955

[5] Chaitkin, Gabriele (transl.). "Correspondence of Georg Cantor and J.B. Cardinal Franzelin". *Fidelio*, vol. III, nº 3, Fall 1994, p. 97-116

[6] Croca, José. "Hyperphysys – the unification of physics", in J.R. Croca and J.E.F. Araújo (eds.), *A new vision on physis*. Lisboa: FCT/CFCUL: 2010

[7] Courant, Richard and Robbins, Herbert. *What is mathematics?* New York: Oxford University Press, 1996

[8] Ende, Michael. *A história sem fim*. São Paulo: Martins Fontes/Editorial Presença, 1990

[9] Dunham, William. *Journey through genius. The great theorems of mathematics*. New York: Penguin, 1991

[10] Fuchs, Walter. *Matemática moderna*. São Paulo: Polígono, 1970

[11] Meschkowski, Herbert. *Problemgeschichte der neueren Mathematik (1800-1950)*. Mannheim, Wien, Zürich: Bibliographisches Institut, 1978

[12] Paoli, Dino de. "A refutation of artificial intelligence". *21st Century*, vol. 4, nº 2, Summer 1991, p. 36-54

[13] Paoli, Dino de. "Mathematics and the paradoxical in nature". *21st Century*, vol. 10, nº 2, Summer 1997, p. 22-35

[14] Parpart, Uwe. "The concept of the transfinite". *Campaigner*, vol. 9, nº 1-2, January-February 1976, p. 6-68

[15] Penrose, Roger. *The emperor's new mind. Concerning computers, minds and the laws of physics*. London: Vintage, 1989

[16] Plato. *Philebus*. Translated by R. Hackforth in E. Hamilton and H. Cairns (Eds.). *The collected dialogues of Plato*. Princeton: Princeton University Press, 1980.

[17] Rucker, Rudi. *Infinity and the mind. The science and philosophy of the infinite*. London: Penguin, 1997

[18] Sanchez, Antonio Leon. "Sobre la aritmética transfinita de Cantor", in www.interciencia.es (accessed on July 1, 2011)

Chapter 5

Space, Time and Becoming

Rui Moreira[1]
Faculty of Sciences
and
Center for the Philosophy of Science of the
University of Lisbon
Portugal
(ranmoreira@gmail.com)

5.1 Introduction

The situation in which theoretical physics finds itself is deep-rooted. Theoretical physics today is confronted with a problem that was created by the scientific revolution of the seventeenth century. This problem emerged when physics was reduced to the study of the mere change of position, ie, the study of the local movement. This reduction occurred when Copernicus unified two ontologically different worlds, which led Galileo to argue that we should spread the epistemology of Platonic astronomy to physics. If there was a single world, the way to describe it should be the one followed by the platonic astronomy. Aristotelian physics then gave its place to Galilean physics.

Thence the enormous importance attached to the concepts of geometric space and chronological time since the scientific revolution of the seventeenth century. Physi-

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cal space has been identified with an euclidean geometric space, and the fundamental evolution parameter would be a chronological time flowing uniformly in every point of this geometrical space, independently from any chosen observer. Aristotle had established a classification associated with the concept of becoming. He had divided change (becoming) into two major and distinct categories: the substantial change and the accidental change. The latter would be further subdivided into three categories: the quantitative movement, the qualitative movement and the local movement. The scientific revolution of the seventeenth century attempted to reduce the object of physics to the local movement.

However, even men of science that made the scientific revolution of the seventeenth century payed attention to phenomena that could hardly be reduced to the mere movement of material points. Here a material point meant a geometrical point with no spatial extension, in an instant of time with no temporal duration and with a well-defined position in geometrical space. This was the ontological framework on which Newton built his physics. Isaac Newton, for instance, also turned his attention to optical phenomena and to alchemy experiments. He adopted a corpuscular conception of light in order to confine it to the same ontological framework of his mechanics. But it was precisely in this domain that Newton felt himself forced to introduce the concept of an ether whose density would change in the neighborhood of the interface between two different optical media, in order to describe certain phenomena. He needed it to describe the phenomenon of refraction, considering that in that region the optical corpuscles would suffer the action of a force that, in accordance with his mechanics, would deviate them from a rectilinear trajectory. We can see that Newton was forced to consider, in this particular case, that space would possess physical properties, contrarily to the concept of the absolute space. It was an ad hoc hypothesis that was not coherent with a general ontological postulate.

On the other hand, and still in the seventeenth century, Huygens proposed an opposite ontological postulate. He defended that light should be a perturbation of the physical space. He admitted that light would propagate itself as a wave in physical space. However, it would be only by the beginning of the nineteenth century, after the works of Young and Fresnel, that the wave concept of light would have the capacity to describe all optical phenomena known at that period. Throughout that same century, the work of Oersted, Faraday, Ampère and Maxwell, among others, led that process until the acceptance of that worldview. A world filled with an ether that would support the propagation of electromagnetic waves.

We must draw attention to the problem that, even in the electromagnetic theory, there remains a concept of physical space identified with a geometric Euclidean space with the purpose to perform calculations. This was the consequence of the

mathematization of Faraday's ideas performed by Maxwell. Electromagnetic waves would propagate in a euclidean space with the velocity of light. But now material points would not exist with a precisely defined position in the space, nor in a well-defined instant of time. Besides, the concept of space suffers a mutation because it now starts to possess physical properties and looses some of its purely geometric nature. Space, now no longer merely geometric, becomes a main actor in the physics, i.e., comes to be a physical object. The waves, entities with an extensive character, would spread as disturbances of a space full of physical properties. At each instant of time, there would be points in space where those waves would show up and points in space where they would not. In this aspect, however, the concepts of point of space and instant of time would continue to be used. There would be points of space disturbed already and points of space still undisturbed. From a strictly formal point of view, the equation of propagation of waves, or wave equation, continued to describe waves in space and in time. A space and a time that would be divisible to their infinitesimal part, and each infinitesimal part would maintain the same physical significance. There would not be room for any kind of emergence.

The differential equations used in the classical theories of physics are all linear. Infinitesimal calculus is essentially linear. The mathematical space where it works is continuous and we can divide any function defined in it in its infinitesimal parts and, after that, we can sum them up to rebuild the original function. Here the whole is just the sum of its parts. If we consider the physical space adequately represented by this mathematical space, then it will become, inescapably, a linear physical space. A physical space useful to a mechanistic world view, where it would be identified with a huge mechanism. But even mechanisms that are described by a non-linear algebraic law, like the pendulum for oscillations of greater amplitude, the double pendulum, and even the forced double pendulum or the triple pendulum, these two last cases associated to a chaotic behavior, all of them follow a linear differential equation, i.e., Newton's second law. The becoming, reduced to a mere local movement, can be hard to calculate. However, it will be not unpredictable, at least from a theoretical point of view. To achieve this, we must know exactly all the parameters involved, including the initial position a velocity. We will be then emerged in the Laplacian determinism. This standpoint is a demonstration of what I call a childhood disease of science, the scientism, that tends to extend the domain of applicability of a theory to domains where it will not work. In the Laplacian determinism there is no room for free will, and the emergence of life would not have existed.

Chemistry was established as a modern scientific area about one century after physics with Lavoisier. Chemistry, which began as alchemy imbued by an Aris-

totelian vision of the world as well, dealt with other kind of changes. One may say that local movement was completely absent of the discussion within chemistry. Here one dealt with substantial changes and the possibility of transformation of several substances into other substances. Chemistry followed a path almost independent from physics until the emergence of quantum mechanics. It was quantum mechanics which allowed building less fragile bridges between these two areas of knowledge. But even so, there are many works on the history of chemistry that attempt to show how quantum mechanics itself is viewed differently by a theoretical physicist and a theoretical chemist. The object of study is different and, therefore, the way to look at the theory is also different as well. Even thermodynamics, a very particular theory of classical physics which deals with the possibility of converting heat into work and work into heat, and that had apparently fallen out of the problems studied in mechanics and electromagnetism, allowed us to establish some links between these two areas knowledge. The transformation of work into heat corresponds to a transformation of a physical quantity correlated with the local movement, namely the kinetic energy, into another one that we cannot correlate with the local movement. The kinetic theory of gases, and later statistical physics, tried with success to reduce the interpretation of thermodynamic quantities like temperature, pressure, entropy. So, even in thermodynamics, physicists tried to reduce it ultimately to the local movement. We can say that physicists tried to reduce every physical theory to a Newtonian ontological framework. It was the emergence of special relativity on one hand, and quantum mechanics on the other, that presented the first serious challenge to the Newtonian ontology. Both these two new theories were born from the necessity to conciliate the two major classic theories, i.e., Newton mechanics and Faraday-Maxwell electromagnetism. I must stress that I just used the term conciliate and not unify. In fact, until today no theory worthy of this designation has reached this major purpose.

5.2 Special relativity and general relativity

By the end of 19th century all attempts to find a mechanical ether, i.e., an ether that would obey Newtonian mechanics had failed. During this process Lorentz found the transformation laws that maintained the form of Maxwell laws of electromagnetism when we change from one inertial frame of reference to another, the so-called Lorentz group. These transformation laws are different from the transformation laws between inertial frames of reference that maintained the form of Newton's laws of classical mechanics, the so-called Galileo group. We must stress that the introduction of inertial frames of reference in the framework of electromagnetism ensued from the attempt to subjugate electromagnetism to Newtonian

mechanics. In the framework of Newtonian mechanics the concept of inertial frame of reference represents a foundational role. The first law of Newtonian mechanics introduces this concept, because it was essential to arrive at the second law, the fundamental law of dynamics. Newton associated it to the concepts of absolute space and absolute time. A space that would be a mere stage where material points would play their role under forces that would act on them instantaneously at distance, and a time that would flow at a constant rhythm independently of any change that our senses would be able to apprehend. Special relativity leads us to give up compulsorily these two metaphysical concepts, but has not abandoned the concept of inertial frame of reference. And a question immediately emerges: why should radiation phenomena be submitted to a concept that only makes sense within a physics that is exclusively concerned with local movement? As we said, such a concept makes sense in the context of a physics that admits the existence of bodies built from material points to which we can attribute a precise position in space. A position identified with a point with no extension in an euclidean space, in an instant of time with no temporal duration. However, special relativity breaks up with the linear sum of velocities. When we reach velocities that are non negligible as compared with the velocity of the light, the linear sum of velocities doesn't give the final velocity. This is the major breakthrough that emerges from special relativity. Even if the concept of inertial frame of reference remained in relativity, it was associated with a new conception of inertia. Inertia becomes a relational concept and not an absolute one. Special relativity emerged from the attempt to conciliate the two above mentioned classic theories following an essentially formal path. Einstein, its founder, was under the influence of Ernst Mach's epistemology, according to which we must avoid committing ourselves to any kind of ontological compromise. Special relativity remained attached to the concept of inertia because Einstein did a merely formal attempt to conciliate classical mechanics and electromagnetism, transforming the first into a relativistic mechanics. In this way, the conciliation performed by Einstein followed a weird compromise. Mechanics should be transformed to become invariant for the same Lorentz group that leaves invariant Maxwell's equations of electromagnetism. But the Lorentz group emerged from the process to find an ether that would obey Newtonian mechanics. A purpose that had failed. We should stress that relativistic mechanics didn't give up the Galilean purpose to build a physics reduced to the mere description of local movement of material points. A reduction that Newton followed to build his mechanics. Another consequence of special relativity was what Bergson called the spatialization of time. Time become another coordinate similar to the other three space coordinates. We could use the term geometrization instead of spatialization, because time becomes itself explicitly integrated in a geometric description of phenomena. It constituted a new step towards an identification of geometry

and physics. A new geometry that significantly received the name of Minkowski space. Time became a new spatial coordinate of a generalized space. This is why Bergson used the term spatialization of time. We must stress that we remain attached to the reductionism introduced in the 17th century scientific revolution, but now a generalized one. Now we can consider a well defined event associated to a Minkowski geometrical point with no space-time extension-duration. It is important to detain ourselves on this point. May be we can try to clarify some, at least apparent conceptual incompatibilities between special relativity and quantum mechanics. Recently, J. Croca proposed that the invariance of the velocity of light for every inertial observers could be related to the ontological compromise adopted by the scientific research program proposed by Louis de Broglie. In this research program it is assumed that every quantum particle should be considered a complex structure, without a well defined position or well defined borders, constantly interacting with other complex structures and reacting in a way compatible with its own structure. In this framework we can advance from an inevitably poor ontological view of a quantum particle constituted by a small region called the acron where it exists a big concentration of what we can call energy, within a larger region where it exists what we can call a ? wave, or sub-quantum wave, that cannot be considered isolated from the acron. They form a complex structure and the ? wave constitutes what we can consider the "sensorium" of that structure. The acron would be the central processor. They would constitute what we can call an indissociable monad. This structure would be in a permanent becoming. This becoming should not be strictly associated with a mere change of position, no longer associated only with a mere well defined situation in space-time – what would be the well defined situation in space-time of a complex structure? - but also with structural changes within it and within other structures interacting with it. The principle of eurhythmy introduced by J. Croca enables us to foresee a possible way for the emergence of more complex structures, that we can designate as physioms, a neologism taken from the biological concept of symbioms, with properties that for the moment we are not able to anticipate. This principle emerged within the scientific research program proposed by Louis de Broglie where he introduced the term sub-quantum medium. This leads us to admit that physical space can hardly be associated with a mere geometric space-time. A geometrical space-time that we always associate with the concept of frame of reference wherever it would be an inertial one associated with an euclidean geometric space or a Minkowski space-time. General relativity intended to insert gravitation in a conceptual framework that would be more coherent with relativistic mechanics. Newtonian gravitation, that special relativity wanted to conciliate with electromagnetism, was not a field theory as electromagnetic theory essentially was. For example, special relativity imposes a limit for the velocity of transmission of a signal – the speed of light –

while Newtonian gravitational interactions act instantaneously at distance. This was another problem created by special relativity that general relativity intended to solve. It was associated with Newtonian gravity itself, because it was related to distance only. In special relativity distances are not invariants and, for that reason, Newton's gravitational law should be modified. All this seems reasonable. The unreasonableness of extending the concept of inertial frame of reference to electromagnetism, which was in the genesis of the Lorentz group, created the need to give up the concept of inertial frame of reference, because general relativity should be a field theory. It would be a field theory freed from the yoke of the concept of inertial frame of reference. However, it will identify physical space-time with non-euclidean geometrical spaces that had emerged throughout the 19th century with the works of Riemann, Lobachevski and Bolyai. The only ontological compromise was to consider the concept of field as foundational ontological concept, as Faraday did. From then on, the masses would be merely regions of space where the concentration of field would be strong enough to be perceived by us as qualitatively different. This idea of Einstein's is similar to the ontological compromise of Louis de Broglie in quantum physics that I mentioned before. Naturally, Louis de Broglie accepted general relativity enthusiastically. However, when we analyze the genesis of Einstein's equation for general relativity, its main goal is to identify the physical world to a geometrical space with four dimensions, where, once again, the trajectories would be defined by the curvature of these geometrical spaces , i. e., the geodesics. We cannot ignore the some formal successes attained by general relativity, for instance, the proof that Newtonian mechanics is a limit case of general relativity. In fact, if we consider that the velocity of light tends to infinity we obtain Newton's gravitational law with its attractive character, the equations of fluid mechanics, such as the continuity equation and Euler's equation, the laws of conservation of mass, energy and momentum, and as it should be, the reduction of non-euclidean spaces to an euclidean space. Despite these formal successes, we must not ignore the fact that no theory worthy of this designation could until now unify gravitation and electromagnetism. Of course, if we substitute the energy-momentum tensor of gravitation with the energy-momentum tensor of electromagnetism we obtain the so-called Einstein-Maxwell equations. But this process is nothing more than a formal "pastiche". No one until now has been able to build an unified theory of these two types of interaction, a theory worthy of this name. A theory supported by a coherent enough view of the world, i.e., an ontological compromise that would be helpful in building a new noetic structure that could be considered a sophisticated machine-tool. Besides, general relativity itself didn't enable us to increase our capabilities of acting in the world. The ultimate criterion for judging the plausibility of a theory is not fulfilled by it. General relativity presents itself as a formal extension of Newtonian mechanics,

but it is just that. Its ultimate intention is to reduce gravitation to a geometrical description. It tries to be a geometrical description of the gravitational field. But it did not open the possibility to create a field theory, worthy of this name, that unifies electromagnetic field with gravitational field. In order to finish my considerations on general relativity we need to stress that theoretical physics is too much committed to a certain way of doing science that is a legacy of 17th century scientific revolution. The reductionism introduced by it remains to this day, and general relativity is the last and most sophisticated act of that heuristic process. This led to an epistemology that reveals a certain skepticism. The semantic view of theories forgets the ultimate criterion proposed earlier in this paper for judging the plausibility of theories. We can understand this epistemological standpoint if we become aware of the incestuous relationship between today's theoretical physics and epistemology. Physics is not a mere narrative. Physics tries to build noetic machine tools. The semantic view of theories tries to justify theoretical conjectures that do not fulfill this criterion. And general relativity did not fulfill this criterion. If we look attentively to the scientific evolution of the last decades, we are led to notice the huge ontic and epistemic turmoil that physical science has lived. We are led to remember the period immediately before the 17th century scientific revolution when it reined an enormous turmoil as well. Koyré characterized the magic of natural renaissance thought with the sentence "everything is possible". In our times it was Feyerabend who characterized the last decades with another sentence "anything goes". We may not accept this stance, and I don't, but we must admit that if we confine ourselves to the activity in theoretical physics, Feyerabend is largely right. This is the main reason why we must impose that a theory must be considered a posteriori as a noetic machine tool. If we impose this criterion then no more we will say "anything goes".

5.3 Quantum mechanics

Quantum mechanics, on its turn, is a theory that fulfills totally the ultimate criterion of plausibility of a scientific theory. It is a theory that has increased hugely our capacities of acting in the world. It enable us to foresee and build instruments that without it were totally inconceivable. We can put it together with Faraday-Maxwell electromagnetism, Newtonian mechanics and thermodynamics. No other theory did it at the same level that these have done. Even special and general relativity didn't achieve it. We cannot consider the technological development that we enjoy today as a product of new physical theories that are presented to us as being as credible as the four just mentioned. None of the so-called physical theories that have been built after WWII surmounted this ultimate criterion. We

must not be misguided by the huge propaganda that does not intend to clarify this fact. Instead, it intends to hide it.

Quantum mechanics, like special relativity, tried to conciliate Newtonian mechanics and Faraday-Maxwell electromagnetism. It emerged from the study of the interaction between matter and radiation. We know that matter had been conceived as constituted by corpuscles, while radiation had been conceived as constituted by waves. Contrarily to the heuristic process followed by Einstein that led to special relativity, the heuristic processes that led to quantum mechanics cannot be considered completely formal. The counterexample was the contribution of the Göttingen school. It followed an almost exclusive formal way. Max Born, Jordan and Heisenberg tried to substitute classical physical quantities by matrices within the classical mechanical formalism. Among these quantities were the position and the momentum. Schrödinger and Louis de Broglie followed instead heuristic processes that started from ontological compromises not totally coincident. Both tried to create a coherent view of the world as far as they could. Schrödinger intended to reduce the physical world to waves. For Schrödinger the world would be continuous and corpuscles would not have an actual existence. They would be mere appearances. Alternatively, Louis de Broglie tried to conciliate waves and corpuscles, and that led him to the conclusion that the new theory should be supported by a non-linear formalism. A non-linear formalism that would emerge from an ontological compromise. This formalism should be a non-linear formalism in order that its solutions could describe a quantum object as a complex structure, where a small region of that structure would have almost all of the energy. This region would represent the so-called corpuscular characteristics of that structure. The greater part of that structure would have a much smaller energy. This greater region would represent the so-called wave characteristics of that structure. This would be the ontological compromise proposed by Louis de Broglie. This was the reason why the Einsteinian general gravitation had been so acceptable to Louis de Broglie. It is well known how this initial situation evolved. In 1926, while Schrödinger was building his wave mechanics, showing simultaneously that his description of the microphysical world was equivalent to that which emerged in Göttingen, Niels Bohr became acquainted to Heisenberg dispersion relations in February 1927. After that, and appealing to his previous philosophical background, he was able to attain his interpretation of quantum formalism supported in the principle of complementarity. This principle represented a rupture with the view of the physical world adopted since the 17th century scientific revolution. Niels Bohr, contrary to process followed by the school of Göttingen, has not followed a merely formal way. Niels Bohr criticized Heisenberg because he had followed a mere mathematical way to derive his dispersion relations. He argued that we must look for the physics behind that formalism. It was from this attitude of Niels Bohr that three

names stand out in the final step in genesis of quantum mechanics: Niels Bohr, Erwin Schrödinger and Louis de Broglie. These three physicists proposed three different scientific research programs that progressed in a mostly autonomous way. As we know, the Niels Bohr program became the dominant one. But the program proposed by Louis de Broglie is nowadays the most credible alternative. There is in the scientific literature a wide set of proposed experiments for which the expected result is different from the result expected by the dominant program. Without going into detail, the principle of complementarity proposed by Bohr states, in its most general enunciation states that it would be impossible to achieve simultaneously a spatio-temporal description and a causal description of microphysical phenomena. It was this principle that led Popper to talk about the "schism" in the 20th century physics. Schrödinger, Louis de Broglie and even Einstein himself, who became the most popular opponent to the ideas of Bohr, could not accept the rupture proposed by Bohr. Bohr's proposal can be considered as path forward in the direction designed by Kant with his Copernican revolution. Kant proposed to consider, against Newton concepts of absolute space and absolute time, that space and time would be, as he called them, a priori forms of intuition, i.e., something that belongs to the subject and not to the object. Space and time would not exist by themselves. They would be a mere subjective framework which we rely on to integrate all the information that our senses apprehend. For Kant, behind these a priori forms of intuition, there are categories or a priori forms of understanding, from which we must emphasize the real category causality. Real categories are the categories we apply in the sciences of nature like physics or biology. The step forward that Bohr did take was to consider that there should exist a relation of complementarity between the Kantian a priori forms of intuition and the real category of causality. He defended that it would be impossible to get a description of phenomena in space and time and establishing causal relations between them simultaneously. The category of causality permeated each one of Newton's principles. The principle of inertia, the fundamental principle of dynamics, the principle of action and reaction and the universal principle of gravitation, all them are imbued with the category of causality. Explicitly or implicitly all of them establish a cause-effect link. Newtonian physics intended to get a description of phenomena in space and time and establish causal relations between them simultaneously. We must remember that Newtonian physics reduced the object of physics to the description of local movement. This is a consequence of the reductionism introduced by Galileo as the core player in the 17th century scientific revolution. Although, as we said before, Newtonian physics had to endure a confrontation against the concept of field throughout the 19th century, it was the emergence of quantum mechanics, and the principle of complementarity, that gave the most serious blow against it. Quantum mechanics then came to say that in the micro-physical world,

the a priori forms of intuition, i.e. the space and the time, on the one hand, and the real category causality, as an a priori form of understanding, on the other, could not be widely applied. In fact, the more we want to describe the phenomena in the framework of space and time, the less able we are to establish causal links between them and vice versa. Special relativity had put into question the concepts of absolute space and time, and general relativity had put into question the appropriateness of using the concept of inertial frame, now, quantum mechanics called into question the very foundations of the scientific revolution of the 17th century. The reductionism to the description of the local movement had reached its limits of applicability. Paradoxically we still keep using concepts that are adapted from others that emerged in the framework of Newtonian mechanics. We used the Lagrangian, the Hamiltonian and position in space or quantity of motion for a microphysical being, etc. In quantum mechanics we use the Lagrangian operator, the Hamiltonian operator, the position operator and the quantity of motion operator, etc. On the other hand the formalism imposes the use of the wave concept. But a wave interpreted as a wave of probability. This is inevitable from a realistic point of view, because the wave-corpuscle dualism, interpreted by the complementarity principle, could never allow an adequate description of a complex structure. In that structure, the wave and corpuscle components are fully recessed into one another. The complementarity principle interpretation of the wave-corpuscle dualism gives up the quest to find a theory able to unify gravitation and electromagnetism. Our own cognitive constrictions prevents us from reaching it. This is a very important cause to the huge ontological, and consequently, epistemological mess in which theoretical physics has been living. The program proposed by Louis de Broglie, on the other hand, intended to give a realistic vision about what could be a quantum being. Within this scientific research program a quantum being should be considered as a complex structure permanently interacting with other quantum beings. Quantum beings occupying different regions of space. The concept of space remains present in this program, but it is a physical space and not a mere mathematical space, even though we are still using mathematics to describe it. Louis de Broglie was quite aware of the pique of this situation. He always called attention to the fact that we must be very careful with the identification of abstract mathematical spaces with the physical space where phenomena occur. Under the scientific research program of Louis de Broglie, José Croca called our attention to the consequences of the implicit acceptance of, as he called it, the Fourier ontology. An ontology that rested throughout our description of the microphysical world. An ontology that is based on a particular mathematical analysis. An ontology where the basic elements are monochromatic plane waves, i. e., the ensemble of every possible frequencies omnipresent in the whole space and in the whole time. Using wavelet analysis instead, José Croca derived dispersion re-

lations different and more general than Bohr-Heisenberg relations. In this process he derived also a non-linear equation that he called non-linear master equation. The heuristic process that led up to it sought to link the discontinuous vision of the world associated to Newtonian mechanics, represented by the Hamilton-Jacobi equation, that somehow have moved away from this discontinuous vision, and a continuous vision of nature represented by the continuity equation. Within this framework José Croca introduced the principle of eurhythmy, reinterpreting the original idea of Max Born and Einstein correlating the intensity of a Schrödinger wave in a particular region of space with the probability of detection of the acron, through a measuring operation, in this same region of space. This process led him to the proposal of another physics that he called hyperphysics. A new physics that intended to be the next step in the scientific research program of Louis de Broglie. A proposal where we could glimpse the path to the unification of gravitation and electromagnetism. Another proposal for a scientific research program, different from the three above mentioned, was made by David Bohm. The main credit we can give David Bohm was that he have reached an interpretation of the quantum formalism that is different from Bohr's. The celebrated theorem of von Neumann stated that it would be impossible to achieve such a feat. Thus, this no-go theorem had been defeated by Bohm. The David Bohm interpretation of the quantum formalism preserves causality, but embraces non-locality. The David Bohm's interpretation of the quantum formalism reinstates the causality, but maintains non-locality from Bohr. This abandonment of the locality implicitly admitted, as Bohr had done, that space is nothing more than an illusion, since the theory allows for instant interactions at a distance. Also for David Bohm, the only beings who possess privileged ontological status, would be plane harmonic waves, i. e., beings that would exist in all space and in all time, as I mentioned above. For such waves, neither space, nor time would be serious obstacles anymore. But they would be real waves and not probability waves. Thus, the causality defended by Bohm would be supported by omnipresent beings that would have an existence by themselves. It would be the phase relation between them that would create the world as we apprehend it. Bohr's interpretation, on the other hand, is different because these monochromatic plane waves would represent, above all, our cognitive constraints. The principle of complementarity imposes this interpretation. The phenomena would be, above all, a creation of the observer when he performs a measurement, i. e., always, because we are in constant interaction with the world and therefore constantly evaluating it. This interpretation of quantum formalism led some to the conclusion that quantum mechanics would be a major proof of God's existence. It is to push too far the application of a mathematical formalism... Recently, after Nimtz experiments about tunnelling effect, José Croca proposed that the concepts of space and chronological time – the measured time

– should no more be considered adequate to describe the sub-quantum medium. This because chronological time - the measured time - is measured using the the concept of space in the act of measurement. The concept of space plays a primordial role in any kind of measurement. One possible conclusion we can get from Nimtz experiments is that, in tunnelling conditions, the chronological time elapsed between the beginning of the contact of the quantum being with the potential barrier and the emergence of the quantum being from that barrier is independent from the spacial extension of the barrier. But we may conclude as well that, with the experimental constraints existing nowadays we are not able to detect any difference between the elapsed time in the experiments performed until now. Indeed, Nimtz used potential barriers with a thickness from 12 to 16 cm. Thus, they are not thick enough to enable us to defend categorically that they traverse the potential barrier in exactly the same chronological time. From the non-linear master equation José Croca found a particular solution – with some inevitable approximations – that would represent the following process: the quantum being would submerge in the sub-quantum medium in the beginning of the barrier, and it would emerge from the sub-quantum medium in the end of the barrier. The quantum entity would not have crossed the barrier keeping its structure and therefore we could not speak of a mere local movement. Perhaps we can conclude that the tunnelling effect is the most serious anomaly questioning the epistemological revolution of the 17th century that wanted to reduce all change to the local movement. If we admit that such a solution may somehow represent what happens inside the tunnelling barrier, it would be no more the inability to assign a well-defined position (to a material point without spatial extension) at a well-defined moment (without time duration) that quantum mechanics imposes. This may be the first evidence that the local movement is a particular feature, and perhaps the least significant, of becoming. If this is so, we may state that the local movement would be an appearance of something deeper: the permanent submergence and emergence of every being in the becoming. A permanent submergence and emergence that may be reduced, for the overwhelming majority of cases and for practical purposes, to local movement. But one thing is to draw attention to the dangers associated to the attempt of reducing any change to the local movement. Another thing is to say that at the scale of complexity of the sub-quantum medium, the space is a concept that we should abandon. The existence of the sub-quantum medium is a foundational ontological postulate for the scientific research program of Louis de Broglie. However, we must admit that we possess scarce empirical information about it. Perhaps the tunnelling effect is a door that will allow us to increase our understanding of the structure of matter. But we must remain aware that this new vision of the world, i. e., this new ontology, must be associated with a new epistemology and a new linguistic-formal component, in order to build a new physical theory, a new noetic

machine-tool, that should enable us to conceive and to build new instruments that would be inconceivable before that new theory. This is the only way to avoid the Feyerabend's statement: "anything goes".

Chapter 6

Insufficiencies and possibilities of the Phenomenological Description of the Ontological Region "Nature"

Pedro M. S. Alves
Department and Center of Philosophy
Faculty of Letters
University of Lisbon, Portugal
(psalves2@gmail.com)

6.1 Two central theses of transcendental phenomenology

The transcendental phenomenology first proposed by Husserl –a mathematician who studied with Weierstrass, and then converted to Philosophy under the influence of Brentano–, is supported entirely, in my opinion, on two main tenets. The first is hardly a controversial one. It is the thesis of reflective self-access. Its formula would be:

> *A*. Starting with the consciousness we have of things in the world, we can always retrogress from the objects of experience to the very experience of objects, convert this experience into a theme of reflective analysis and explicate its sense-content.

When systematically accomplished, Husserl characterizes *A* as a change of attitude, namely, the change that converts the natural stance into the transcendental stance. The natural stance is typically interested in things that are experienced; on the other hand, the thematic interest of the transcendental stance concerns the very experiences in which things are given and known, or, in the phenomenological parlance, concerns things as phenomena. For instance, natural thinking makes assertions about physical space, tentatively determining its structure and properties; phenomenology, however, is interested in phenomenal space, i.e., in space as it appears as a correlate of intentional acts, so that while physicists aim at the knowledge of objective space, phenomenologists query about the sense-content of the experience of space, and about the way it constitutes as something objective that empirical science can, then, take as a theme. In fact, physicist queries about space (as well as all forms of straightforwardly oriented research) develop under the naïve acceptance of objective space as something at-hand, i.e., as something the existence of which is simply accepted, and the possibility of it being known is not questioned. Phenomenologists, instead, takes a step back and methodically retrogresses from objective space to the subjective performances by which something like objective space is always there for us. They uncover a constitutive activity of consciousness that lies beyond the reach of any research in the framework of the natural stance. As a matter of fact, this regress to subjective performances is understood by the natural stance as a return to psychology. However, phenomenology displays a radically new comprehension of subjectivity: it is constitutive of any objective reality as given in the world, rather than an object in a world already –and mysteriously– present for us. In this vein, phenomenologists will first describe perceptual space (i.e., space as correlated with the primordial experience that gives access to it), they will then exhibit the processes of idealization by which perceptual space gains new properties and structure so that it becomes the space that Euclidean geometry takes as its theme and, finally, how new mathematic processes of formalization – for instance, the Riemanian manifolds – give rise to the scientific concept of space modern physicists are concerned with. Phenomenology is, thus, a method for systematically retrogressing from the objects that are given to the consciousness of these objects, showing how they can be present for us as the things they actually are. It does not describe the real genesis of things and of the world as a whole. Rather, it describes the sense-given formations by which things are there for us as something the existence of which the natural stance naively takes for granted.

This is the first thesis of phenomenology. In order to express it in the most general form, one could state: we can always return from the world we experience to the very experience of the world, i.e., to the world-phenomenon, wonder about the sense and content of this experience and place it as the theme of a non-natural

science of consciousness, searching for the system of pure possibilities of experiences in an *a priori* fashion. In so doing, phenomenology does not affirm that there is a world, namely this world we live in; it describes the possible forms of world-consciousness and world-experience as such, i.e., as a system of pure possibilities, disregarding any question about a factual, actual world.

While it is, to a certain extent, embedded in the first, the second thesis of phenomenology is also, however, a highly controversial one. It is the thesis of synthetic *a priori* knowledge. The formulation runs as follows:

> *B.* From the *sense* of our experience we can derive essential laws that constrain concept and theory formation in natural-stance sciences, so that, for every science, be it formal or material, there is a set of essential laws that forms its *a priori* basis.

Transcendental phenomenology presents these essential laws as prescriptions that are necessarily true for all objects of every possible experience. They are of two types. There are, on the one hand, prescriptions of a formal nature: they refer to the sense of being an object of possible knowledge, and they deal with the predicates that characterize objectivity as such, disregarding its material nature. They are, thus, prescriptions about the highly abstract form "object whatsoever" or "as such". The complex of sciences related to the form "object whatsoever" gives rise to an Universal Mathematics in the sense of Leibniz's *mathesis universalis* (it includes, for instance, logic, set theory, formal mathematics, and so on, and it comes to a final point with the theory of manifolds, as a theory of the possible forms of theories in general). Husserl accounts for this *mathesis universalis* as a formal ontology, setting the sense of general determinations like "property", "relation", "unity", "set", "manifold", and so on. On the other hand, there are material prescriptions, i.e., prescriptions not about the general form "object as such", but about its possible content. A step beyond simple ontological-formal determinations, the system of concrete material ontologies queries about what is to be an object of a determinate nature, with a concrete content. The summa genera for each material set of determinations are called "regions". There are supreme genera like "nature", "living being", "psyche", "social world", etc. These new prescriptions of a material brand are also essential laws. Therefore, they impose necessary constraints for every object falling under a material, regional concept. Thus, if an individual X is given with the sense of a natural being and living organism, then we would know in advance, before any empirical research, that X verifies some formal properties pertaining to the region "object as such", and all ontological-material properties belonging to the regions "natural world" and "living world". Fixing the essential laws as invariants for each material region as well as for the relationships of foundation and mutual connection between regions is the main goal of the whole system

of regional ontologies. Formal and regional ontologies form together the realm of *a priori* knowledge. This *a priori* piece of knowledge refers not only to the actual world and to its objects, but rather to every possible world and to every object of a possible experience. Indeed, for phenomenology, there is no world without an experience related to it, so that the multiple thinkable forms of experience exhaust the multiplicity of possible worlds. For instance, in the realm of pure possibilities, one can think about worlds with different empirical laws; however, if in a possible world there is the region "nature" and the region "living organism", the objects falling under them would contain a nucleus of invariant essential laws, despite the fact that, in these worlds, say, the gravitational constant can be different, c can vary also from world to world, and the "tree of life" can have another configuration. The same reasoning can be done for any law, so that, if the law at stake can vary without contradiction, it will be an empirical, contingent law; on the other hand, if a law cannot vary without destroying the very concept of an object of a determinate material essence (for instance: not having extension in space for an object belonging to the region "nature"), the law in question will be an *a priori* essential law, necessarily prescribing some properties as an invariant core. It is this invariant – named "eidetic law", from the Greek *eidos*, meaning "form", "essence" – that makes up the content of the *a priori* sciences.

6.2 An argument for eidetic laws and *a priori*, synthetic-material knowledge

As I said above, this second thesis is highly controversial. In fact, it gives expression to an immodest ambition: nothing less than to know in advance, and in a definitive way, what is, say, a living being in general, a natural being in general, a psychic nature, or the "essential" content of any other ontological region, and to know it not with a validity confined to the actual world, but, unconditionally, to every possible world that could exist instead of ours. We are not dealing, thus, with inductive laws, the validity of which is not only provisional, but also limited to the actual universe. Instead, we have here universal laws in a strong sense, i.e., laws necessarily applying to whatever objects that may fall under them in any possible world that could ever exist. Further, these purported laws do not come from empirical research (for instance, the cognizance of the fact that life is based on organic chemistry), given that this kind of knowledge refers to contingent features of the existing universe which are not invariant across possible universes (indeed, we can think of another possible universe in which the "essential" properties of living-beings are instantiated in another material basis). Here is the claim for an

"eidetic", pure, *a priori* knowledge made by phenomenology: on the one hand, it must be related to possible worlds (i.e., to possible systems of concordant experience), in order to catch an invariant core, the supposed "essence"; on the other hand, it must be related to empirical knowledge, to put forward different sets of necessary properties which direct and constrain empirical research. In a word, it is the demand for knowledge of invariable properties across multiple individuals along possible worlds, and, at the same time, for circumscribing a necessity-nucleus in empirical knowledge. However, this huge claim by phenomenology seems to be rooted on a rather narrow basis: the sense-content of our experience of the actual world. As a matter of fact, for the extraction of these material essential laws, the phenomenologist has no other source than the sense of the experience of our real world, and, over and above it, some methodological procedures such as neutralization and free variation in phantasy. The question is whether these last methodological devices are strong enough to produce an *a priori* science that would be able to capture a necessity-core constraining empirical laws. Indeed, one can wonder if the experience of the world is not bounded to this very real world we have experience of, namely, to its nature and composition. How can we disentangle a piece of it and affirm its universality, so that we could obtain something like an essential law remaining valid across every experience related to every possible world? Can we know for sure (i. e., apodictically) that the progression of our empirical knowledge will not falsify a purported "essential law"? To sum up, how does phenomenology justify all these claims, which are implied in what we have called its second thesis, i.e., the thesis of a material *a priori* knowledge? Actually, this second thesis entails a conjunction of three sub-theses, which have different levels of plausibility. They are the following:

> B.1. The *semantic-descriptive thesis*: our experience contains a sense, which can be described, and this sense has invariable nuclei for every possible experience: these nuclei can be asserted in the form of a set of universal laws (in a synthetic *a priori* judgment).
>
> B.2. *The thesis of subsunction* (or *connotation*): every object that is experienced with the sense A (as an A, for short) verifies necessarily *in experience* (or *as experienced*) the universal properties belonging to A.
>
> B.3. *The cognitive thesis*: if an object X is experienced as having the properties belonging to A, then it really has (i.e., in itself) the properties of A.

Sub-theses B.1. e B.2. are almost uncontroversial. Obviously, the experience we have of the world is not semantically empty. Furthermore, the sense content of the experience is not merely a pragmatic one. Things experienced show themselves

not only with predicates linked to our active intervention in the surrounding world, like "useful", "harmful", "boring", etc. Instead, they are recognized *as things*, i.e., as having determinations that characterize them in their own being. There are things which are apprehended as natural beings; there are things that, over and above the sense-stratum of simple nature, are apprehended as living things, i.e., as organisms, or as psycho-somatic beings. The fact that our experience is semantically structured not only entails that its sense-content can be explicitly expressed (in a kind of reflective analysis thematically directed to it), but also that everything is apprehended in a net of interconnected senses. These senses form a system, and the system of interconnected senses gives rise, in its turn, to what we call the all-embracing sense "world", so that our experience is, at last, experience of one and unique actual world.

However, with theses B.1. and B.2. we are just describing features of our experience of the world. But can we project the sense content of our experience of an object into the very object we are experiencing, so that what is valid for us is objectively understood as a feature of the very things we are experiencing? If this were the case, from the sense content of our experience we could reach objective properties that would be true about the things themselves, no matter if experienced or not. This is what is really at stake with thesis B.3. After a closer look, there are two different claims here. First, the claim that the invariant nuclei remain valid for every possible object of any possible world (with the condition that these possible objects fall under the conceptual sense in question); second, the claim that the progression of empirical knowledge within the actual world will never contradict the invariant nuclei we have put forward as an *a priori* universal knowledge. Here is the controversial feature of thesis B.3. Stated in a general way, it amounts to saying that

> B.4. If a thing has, for an experiencing subject, the essential properties p1, p2, ... pn, then it has *objectively* the properties p1, p2, ... pn.

As I said, this is a controversial thesis because it makes an extrapolation from the way things are given (in experience) to what things are (objectively), an extrapolation that is based in the very way things are given. No need to say that this sounds like a *petitio principii*. The whole question depends on the interpretation of the word "objectively". For instance, according to the sense of our experience of a being endowed with a psyche, its mental life is apprehended as linked to a body, but, at the same time, as different from the body. The mental, as apprehended in the experience of ourselves and others, is neither localized in any particular part of the body, nor in the body as a whole. In one word, the sense of our experience suggests something like a distinction and a quasi-separation, but still within a close union, of body and mind. It is in this way that we recognize something as a

subject endowed with a mental life. Nevertheless, it does not follow from the sense of our experience of the mental that the psyche *is, in itself*, something different from the organic body and irreducible to it. From the way mental life is given in experience (to itself or to other subjects), we can develop either a "Cartesian" theory about a real distinction between soul and body, or a "materialist", reductionist theory about the equivalence between the mental and the organic (neurological) phenomena. The way of giveness does not imposes a unique research direction when we come to theoretical thinking, aiming at the determination of what things "really" are. Focused on the sense of our experience of the world, phenomenology cannot suggest or preclude ways of research for theoretical, scientific thinking. Indeed, the research hypotheses guiding empirical inquiry can be pretty far away from the sense of our immediate acquaintance with the world. To remain with our former example, some work in neurological science suggests quite the opposite of our immediate experience of the mental, i.e., it suggests neither a distinction nor a separation between mental life and its bodily "base", so that, contrary to the sense of our experience of ourselves and others, the mental is nothing but a phenomenon of the neuronal net in our brains. This is, no need to say, a hard hypothesis. It is open to discussion. But a decision, if we can reach one in the future, will not come by an appeal to the "sense content" of our experience of mental life. With all its putative *a priori* knowledge, phenomenology seems to be simply enthroning a naïve, pre-scientific view, and is, therefore, disregarded in the scientific debate about the question. The same situation can be found in many other fields of knowledge.

How does phenomenology justify its claim, i. e., B.4. or the move from the sense of our experience of things to the objective determinations of what things "essentially" are? Here we enter the very center of the phenomenological justification of the *a priori* knowledge. Actually, phenomenology does not propose a direct justification. Instead, it puts forward a set of theses that to this passage a look of plausibleness.

First of all, phenomenology is in keeping with the idea that there is a pre-theoretic experience of the world, in the double sense of it being independent and previous to any scientific concept formation and explication. This idea sprung from Mach's positivism and Avenarius' empiriocriticism. Husserl reworked it giving rise to the phenomenological program of a description of the "natural concept of the world" (the expression was coined by Avenarius himself). In Husserl's phenomenology, the description of the natural concept of the world is tantamount to describing our perceptual acquaintance with the world (above the lower strata of passive synthesis), and, as a theoretical program, it was renamed by Husserl in the mid-twenties as the description of the sense structures of the "life-world" (*Lenbenswelt*), as a world

of pre-predicative experience. According to it, there is always an experience of the world with semantic and logical content, while independent of any scientific theory. This experience will remain identical the same in its sense content and typical structure across the changes of scientific hypothesis. As a matter of fact, Aristotle's and Newton's physics are pretty different regarding theoretical concepts and explicative procedures. Nevertheless, Aristotle and Newton had before them, in their pre-theoretical experience, a world that was arguably the same, when we consider its phenomena and the typicality of immediate, perceptual acquaintance. It was a world viewed from Earth, with bodies, motions, stars and planets. And natural things behaved in the very same way: bodies fell to the earth when dropped, etc. It was indeed to this perceptual world of pre-theoretical experience that the statements of their physics ultimately refer back. Thus, this phenomenological thesis is quite plausible, as long as we abstract from the historicity of interpretative concepts already used in pre-theoretical experience, considering only perceptual acquaintance and the logical structure of immediate experience. We will make use of this idea, which seems plausible and uncontroversial to a certain extent.

However, the second idea of transcendental phenomenology is plainly metaphysical. It states a world is always the correlate of an actual experience, so that thinking about a world without a correlated subjective experience is nonsense for phenomenology. There is a world as long as there is subjective experience of and knowledge about it. In these matters, phenomenology is a kind of radicalized Kantianism. In its "Copernican revolution", Kant showed that cognition cannot be accounted for as a kind of specular image of things in themselves. Quite the opposite, the object of knowledge is the result of a set of logical and categorical procedures, which Kant divided in conditions relative to intuition (*Anschauung*), and conditions relative to conceptual thinking (*Begriff*). Notwithstanding, Kant made a crucial distinction between things as they are in themselves and things as they appear to a subject, showing that the object of knowledge refers only to appearances (*Erscheinungen*), leaving untouched things as they "really are" (i.e., in themselves, not as phenomena). Thus, Kant did not abolish the metaphysical distinction between reality and the realm of appearances, which exists only inasmuch as there is a knowing subject. Reality "in itself" is independent of the existence of a knowing subjectivity. Phenomenology is a kind of radicalized Kantianism because it suppresses this concept of a reality "in itself" (or "for no one"), defending, in its place, that "reality" is the correlate of justified, valid beliefs and, thus, a sense-formation dependent on the activity of a knowing subject. Therefore, there is no reality "in itself". There is such a thing as "reality" whenever and wherever there is a consciousness *of* reality, so that we cannot disentangle the two branches, and construct the former as a kind of realm of being, existing by itself. To put it in a nutshell, if "what exists" is recognized and posited as "reality", then there is a

cognizing subject that performs the acts of believing and positing that construct, this "reality" as a sense formation correlated with a conscious experience. Talking about reality is, thus, talking about intersubjective forms of validation and verification. *Constitutive* phenomenology is particularly concerned with this task, i.e., with the study of the conditions under which an object intended can be posited as "real". This is, in the phenomenological jargon, the field of research named "phenomenology of *reason*". Describing the experience of such a subject, inasmuch as it is constitutive of reality, is tantamount to describing the intentional life of a subject which is not part of the world, but precisely a subject *for* the world, i.e., the instance from which there is such a thing as an experience that has the real as its intentional correlate.

The third idea has an epistemological imprint. Having no more room for the naïve realist notion of a realm of reality "in itself", independent of a knowing subject, the phenomenological thesis, according to which we can extrapolate from the sense of the experience to what things are, will not mean that phenomena are the same as reality or, to say it in another way, that reality will be "nothing more than" simple phenomena. Rather, it means that, going beyond what appears in perceptual experience, scientific research must, however, stay in keeping with the sense of this pre-theoretical experience and with the essential laws that regulate it, laws which are "trans-worldly", so to speak, i.e., valid for any possible experienced world whatsoever. The controversial thesis was, in my rendering, that "essential laws about the objective world are derived from the sense of the world of experience". The phenomenological meaning of this assertion amounts to stating that scientific inquiry, whose correlate is the *objective world* "behind" experience, must, for a start, get its fundamental concepts from the world of pure experience, and, secondly, develop the scientific thinking in accordance with the sense of that experience, under the essential, *a priori* laws that develop from it. All empirical science stands under *a priori* laws, and these laws are an expression of the activity of consciousness through which the objects of research are constituted. The most fundamental layer of this *a priori* science, paving the way for empirical research insofar as it constitutes primitively the very objects it takes as given, is, as we saw above, the pre-theoretical, perceptual experience of one actual world. In doing so, scientific concept formation, together with its hypostatized objects –such as atoms, sub-atomic particles, waves, fields, and so on– could always regress to the primitive perceptual world, showing the chain of idealizations that originally constituted them. As a result, although scientific thinking embarks on a journey to an "invisible", non-perceptible, conceptual world, it could always reestablish the link between its own realm and the perceptual world already given before any scientific conceptualizations and idealizations.

Starting from this state of affairs, I would like to explore, in the second part of my paper, both the virtuosities and shortcomings of the phenomenological characterization of Nature, submitting to a critical examination the role that the concepts of time and space play in the understanding of what is a natural being. Another critical point will be the phenomenological tenet that empirical science must be in a continuous –yet not homogeneous– track with perceptual belief.

I ask:

I. To want extent has transcendental phenomenology – as exposed in Husserl's classical works –already discovered the deepest sense-structures of the purported "pre-theoretical" experience of the world?

II. To what extent does scientific concept and hypothesis formation, namely in Physics, stay in fact, and *must* stay in principle, in continuity with the perceptual experience and with its inborn beliefs about the world?

6.3 The modern idea about what a natural being is

Regarding I., I'll proceed by putting forward the following general distinctions:

I call "P-experience" the *perceptual grasping of a surrounding world*. I include in such an experience the type of objects that are constituted in simple perceptions, *plus* the typical forms of event ordination, *plus* the logical-categorical formations founded on the perceptual objects by means of judgments (i.e., "state-of-affairs", like "the pencil is on the table", "A > B", and so on). Crudely put, objects given in the surrounding world are individual things, grasped under pre-theoretical concepts like "this tree", "the house", "a living being", etc.; events are ordered in the typical form *if-then*, "if x happens, then it is expectable that y will happen too", a kind of induction which is not yet causality in a strict sense; finally, the logical-categorical activity of judgment constitutes a kind of higher-order objects like, for instance, substrate and property (in the judgment "the sky is blue"), the whole and the part, conjunctive linking or disjunctive opposition, and so on. P-experience is, thus, the experience of a world restricted to the perceptual field and to its internal dynamics of progression, formed by individual things, ordered events, and categorical objects constituted in judicative performances.

In contradistinction, I call "T-experience" the reframing of P-experience by means of an explicative theory, which contains an ontological commitment with certain non-perceptual realities (for start, the objects of the theory, for instance, waves,

particles, mass points, forces, etc.), *plus* a characterization of the order between events we can get in scientific inquiry (which can be classical-causal, focused on deterministic chains, or simply probabilistic, etc.), *plus* a language for the expression of noticeable regularities (in the case of modern science, the mathematical expression of relationships between measurable features of events).

Regarding the relationship between P- and T- experiences, I stress:

(i) *T-experience can be accounted for as a reinterpretation of P-experience*: its objects and causal laws (if any) are literally "sub-posed in" (i.e., posited under, as a "*suppositum*") the objects of P-experience and "seen" in them.

(ii) *T-experience cannot substitute P-experience*: the objects and laws of T are, mostly, conceptually constructed formations and, strictly speaking, invisible as such, i.e., non-susceptible of being given in simple perceptions.

(iii) *T-experience requires a direct or indirect connection with P-experience*: a state-of-affairs in T must be perceptually grasped by means of a state-of-affairs in P, which directly or indirectly "shows" it (examples: cell nuclei are directly shown in an optical microscope, while a condensation line in a bubble chamber only shows indirectly the path of a sub-atomic particle).

(iv) *T-experience is generated from P-experience*: objects, laws, and states-of-affairs in T are constructed through methodological and conceptual operations imposed on the objects of P.

I will not elaborate on each of these four points. Based on the fourth, I will focus on the following issues: firstly, on the methodological procedures of modern Galilean-Cartesian science which has constituted, departing from P, the object proper of Physics, and, secondly, on what transcendental Phenomenology said –and *can* say– about this modern characterization of what constitutes the "physicality" of physical beings, as it was both determined by Physics and Philosophy.

A fully-fledged rejoinder to the first issue should be pretty long, repeating some matters everyone already knows. However, we can stress the following essential points:

Firstly, it is worth remarking the (epistemological as well as ontological) suppression of complexity. The Physics that started with Galileo was based on a generalized procedure of passage to the limit by which, departing from the roughly regular objects of P-experience, regular and (mathematically) perfect objects were idealized. Geometry played an essential role in this early idealization of P-experience. Crudely regular bodies and paths were substituted (and simplified) by geometrically perfect figures and lines. Where exceeding irregularity seemed to preclude

a straightforward idealization, it was supposed that the whole was liable to an in principle always possible stepwise disaggregation, so that, eventually, a multiplicity of geometrically simple elements would be attained. Actually, the corpuscular hypothesis soon became the mainstream opinion in the philosophy of Nature, despite the Cartesian reduction of matter to extension. Soon, this first idealization, which was yet linked to geometrical visualization, attained a higher level of abstraction and encompassed other fields of pure Mathematics, such as Algebra and the new Calculus. As a result, Physics was progressively dealing with mathematical objects as such, forgetting its roots in the pre-given world of P-experience. And even worst, it was not only oblivion, but an entirely new faith that was developing: mathematically framed objects were supposed to constitute the "true" Nature, a step ahead of the bewildering and deceiving objects of P-experience. From now on, Physics was a case of the much richer and broader realm of pure Mathematics, so that one could wonder why, bearing in mind all pure laws of mathematics, God "chose" to "realize" a determinate set of them instead of another (Leibniz embarked famously on such a train of thoughts). By means of such a generalized idealization, a kind of new Pythagoreanism emerged: it was not the case that Nature just mimics the perfect objects of Mathematics, as in the old Platonic lesson, but rather that Nature was mathematical on its own. All complexity should therefore be accounted for as a whole analyzable in simple elements and reducible to the behavior of these ultimate pieces of reality, regardless of whether these last particles were corpuscles or waves. Classical Mechanics was the very first form of this new trend. Instead of assuming that complexity is an encompassing and inescapable phenomenon, so that top-properties of organized systems cannot be analyzed in simple elements plus their individual properties, it was supposed that organized systems were in principle "nothing more" than the result of the blind behavior of their ultimate particles plus the "forces" that amass them. The idea that *organization* is a result of simple, blind *composition* was dominant, despite it quickly showing its explicative limitations. Regarding these explicative shortcomings, the phenomenon of life was a paramount example. However, the very phenomenon of self-organizing complexity is much deeper than life – it reaches all strata of the so-called "inanimate" Nature, which is definitely not a simple assemblage of inert "matter", but a structure already displaying a pattern of organization. For biology, the constant reappearance of teleological and preformation theories certainly gave a bad answer to a real problem: the problem of *self*-organization according to a definite pattern. But the Mechanical approach was even worse: it was blind to the very problem that stands before us, believing that organization was no more than sheer composition.

Secondly, there was an almost complete concentration on the issue of local motion, as everyone knows, which was a dramatic impoverishment of the classical concept

of movement. Indeed, the first great problem of the modern conception of Nature was the question about local motion. An entirely new global idea of Nature stood up based on the idea that every natural phenomenon should be accountable as the result of the simple local motion of its constituent ultimate particles. The theory of Nature should be, therefore, the theory of the motion of matter, i.e., of the very stuff which is susceptible of local motion and which is entirely definable by its mobility. Kant enthroned this modern conception when he defined the object of Physics as "matter in motion", in his *Metaphysical Principles of the Science of Nature*. By means of this one-sided conception, natural being was physically determined through the concept of "mass", the old *quantitas materiae*, and the concept of mass was itself defined as a measure of the resistance to alterations in the state of motion (*vis inertia*). Between a bloc of marble and a living being there is an enormous difference as far as organization is concerned. However, from a strictly mechanical point of view, as it was developed by Galileo, Descartes, and Newton, Physics should consider both as carriers of properties like mass, volume, position, motion, and the like. In a word, they would be equal regarding the concepts Physics puts forward in order to understand a natural being. Paradoxically, therefore, what makes the huge difference between a bloc of marble and a living organism stands beyond the reach of Physics as such. It concerns "other sciences", viz. Biology, as if Physics would be concerned exclusively with a set of basic and simple properties of matter and would have, thus, nothing to say about Nature as a whole and in the fullness of its proper determinations. Therefore, a kind of artificial stratification imposed itself, as if there was a basic stratum of supposedly "strictly physical" properties of matter, and then upper strata of chemical, biological, psychological (and even social and cultural) properties, so that the wholeness of Nature was decomposed in different ontological regions, as if they were kingdoms on their own. Despite reductionist programs' search for a downward link between these strata, modern dualisms –like the dualities of animate and inanimate being, body and psyche, matter and spirit, but also between natural necessity (in a Laplacian fashion) and creativeness– came altogether from this modern impoverishment of the field and of the theme of Physics as *the* science of Nature.

Thirdly, there was a hypothesizing of space and time as the fundamental frames of Nature. Actually, with Newton, Euler, and Kant, the doctrine of absolute time and space imposed itself, despite the objections of a Huygens or a Leibniz. The idea that, in the system of nature, all things bear a primitive relation "to" space and "to" time, in such a way that an empty space and time would be possible, which would have physical and metrics properties independent of the presence of bodies, is an idea so profoundly rooted in the modern conception of nature that generalized relativity still maintains this vision of a structure of space-time itself even when the matter-energy density tends to zero. The question of knowing whether Dynamics

imposes or not the idea of an absolute space and time, as Newton wanted, can even have a negative answer within Physics (let's remember Mach's dispute) – this does not change, however, the basic idea that space-time form a continuum which holds and determines *universally* all beings and events in nature, in such a way that all that is natural involves *eo ipso* a spatial-temporal determination and is defined in relation to all associated physical concepts: localization, position, speed, moment, acceleration, continuity of movement, etc. Electromagnetism, since the 19th Century, and Quantum Physics, in the 20th Century, introduced some limitations to this vision, which originated in classical Mechanics, of a space-time as a universal container of matter in movement. However, the introduction of the concept of referential and of matter's corpuscular vision (the "particle") were still remnants of concepts from classical Mechanics which remained embedded in the core of Electromagnetism and Quantum Physics, giving origin to not few conceptual problems.

I will now turn to the second point: what transcendental Phenomenology said and, above all, can say, about the modern determination of a natural being. What it said is double. On the one hand, the Husserl from *The Crisis of the European Sciences*, in the famous paragraph nine, reveals the idealization operations which "substructed" (his word) an "objective" and "exact" nature, as a correlate of the mathematical sciences of nature, "under" the irregular and subjectively oriented nature of experience-P. On the other hand, in *Ideas I* and *II*, when determining the meaning of a natural being by the notes of *res extensa*, of *res temporalis* and of mobility, Phenomenology remained uncritically within modern idealization and reductions, not making use of the possibilities of its own model of approach.

Now, bearing in mind the possibilities of the phenomenological model, what I propose as a thesis is the following: experience-P definitely has traces that can be found at the foundation of the modern determination of a natural being in Physics. This is the case of approximation to ideal figures and magnitudes (although its reconstruction in exact figures and sizes is an idealization); it is also the case of the mobility of all bodies in relation to each other (although free mobility "in space" is already an idealization); and it is, finally, the case of spatiality, in the sense of "one next to another", and of temporality, in the sense of "one after another" (although the localization of each body in absolute space and time is a new idealization). However, all these determinations *are also said* of non-natural beings (for example, of a technical object or a cultural object like a painting) and none of it captures the meaning of being of a natural being in its most proper core. What is, in fact, in experience-P, the meaning of being of a thing *of* nature? I reply: it is the autonomous emerging (not from a technical activity) of a structure that exhibits a pattern of self-organization – and that organization pattern is exactly

what constitutes a thing as a *being*, and as a *natural being* (the ancient concept of *forma*, *morphe*, finds here its true place); everything that emerges *sponte sua*, and which self-organizes in a stable manner, everything which emerges from itself and which subsists developing itself is a *natural* being. The ancient voice *phyein*, *physis*, meant to say precisely that: to emerge and to grow, in a more fundamental sense than chronological time and biological growth – *physis* is *genesis*, and *genesis* is what we call *becoming*. The Latin word *natura*, from *natus* and *nascere* points precisely in the same direction.

Hence the reason to assert the following: in experience-P, the nucleus of meaning through which one identifies something as *natural* is the spontaneity of self-organization, and the persistence (even if unstable) of that organization in its exchanges with the surrounding world, exchanges which are a source of permanent alteration. The determination of the meaning of a natural being in Physics missed this element when it concentrated, instead, on the idea of a full spatial-temporal universe (or partially full) of matter in motion. What makes a being *a* being, if you'll pardon the somewhat redundant expression, is not, however, being an "aggregate" of matter, whatever that means; it is, instead, being a structure that has reached a level of stability and which subsists, that may develop within the same pattern, or that may disintegrate and give rise to new organization patterns. This richness of the spontaneous generation of patterns is precisely what, in experience-P, we identified as *nature* (in opposition to generation "assisted" by technique). A being which is thus self-organized ("*morphologic*") is a *natural* being. And this is shown by experience-P: the organization is clearly visible in life, where the whole deceptively seems to precede the parts and be their cause (it is this illusion which leads to teleological pseudo-explanations), but the organization comes from further and deeper: the forms of mineral crystallization are a classic example of organization according to a pattern in "matter" which is said to be "inanimate", and which has always inspired natural philosophers. Nevertheless, organization is pervasive in everything: an atom is already a highly organized structure, and the same is true of the *acron* and its *theta-wave*, emerging from the sub quantum medium, even though these objects are *suposita* of T-experience and, therefore, perceptually inaccessible entities.

6.4 P-experience and science

Finally, I will turn to the burning (and pending, *sub* II) question: between perceptive experience and scientific concepts, what continuity or rupture is there, or to what extent is there a continuity (or not), and to what extent is there a rupture

(or not). In a word, to what extent should we believe what perception shows us of the world?

This question has several implications. It involves: (i) a *decision* about the possibility of what Phenomenology designates as synthetic-material *a priori* knowledge (regional ontologies, with their claim to establish truly substantive necessary truths, and not merely formal truths); (ii) a *reappraisal* of the phenomenological theory of transcendental consciousness (namely, of the possibility of naturalizing the epistemic subject); (iii) a *reflection* on the beliefs grounded on perception, maximally, the one that space and time constitute universal, all-encompassing forms for all natural phenomena.

In order to clarify my position, even before I draw any argument, I will say what I aim to defend. It is the following:

Ad (i) I'll say that there is no synthetic-material *a priori* knowledge (although there is formal-analytical knowledge, that is, a mathesis universalis in the sense Husserl gives it in the Prolegomena).

Ad (ii), I'll say that consciousness is not a pure subject for the world (subject which would be as if outside the world, but rather that consciousness is a system of interactions (in our physiological language, we call them "sensations", but they begin at a much deeper level) through which the world appears, and that there are several possible forms of sensibility, therefore, of consciousness of the world, and, thus, of the active and cognitive insertion of a subject in the world.

Ad (iii), I'll say that space and time are valid in the context of our experience-P, that they have a regional application to objects in that P-scale (*grosso modo*, bodies in movement), and for the Physics built upon them, but that when we try to think of them *objectively*, that is, without reference to a localized observer in experience-P, they disintegrate into more fundamental concepts.

In the end, all of that will allow me to say in what degree I believe there is continuity, and in what degree a rupture, between perceptive belief and scientific explanation.

The thesis of a synthetic *a priori* knowledge ("material") is one of the cornerstones of transcendental Phenomenology. Beyond the logical-mathematical representation of "something in general", or of "object X", there would also be a determination of the essential laws of material ontological regions, and those laws would be susceptible of being universalized and exportable to any experience of any possible world. It would be the matter of an *a priori* not relative to this actual world we have experience of, but to any world as such, where such object categories would exist. Nevertheless, if we look closely, there is an artifice that can be uncovered

here, one which reveals the emptiness of the supposed synthetic-material *a priori* knowledge. Logical Empiricism, in its beginning, with Schlick and Reichenbach, had already stood up against the pupated "synthetic *a priori*" knowledge (in the Kantian version), albeit with different arguments. Typically, the transcendental phenomenologist says: we describe any object, let's say, a perceptual experience, and we isolate, through free variation, the essential aspects of that experience, that is, those that are invariant in all forms of perception we can conceive, in the same manner as, in geometrical intuition, we can, for example, freely vary the lengths and the angles of a triangle, while at the same time seeing that, in that variation, there are restrictions, invariable elements, like the existence of three sides, of three angles, the sum of the internal angles, etc., which, if they were varied, would destroy the very object triangle. Those invariant elements, be it in the description of a perception, or of anything else – continues the phenomenologist -, are not truths relative to those objects as they are in our actual world and in our contingent experience, but rather constitute essential laws exportable to any possible world. Indeed, they define *what is* a perception or a triangle *as such*.

Here is the artifice of this reasoning:

1st . One takes any contingent fact from the actual world (say this perceptual act and its object as it appears in perception).

2nd. Then, it is established, by pure stipulation, that this – for example, this act – is what is called "perception".

3rd. What was a contingent fact is standardized – it now appears as a *type*: the perception is that which this act illustrates and, on the basis of a variation of properties, the "essence" (= the invariant) of perception is determined.

4th. A rigid denominator is thus created, in Kripke's sense: "perception" now rigidly designates acts and objects of that essential type, and *not others*.

5th. One now candidly poses the question: if there is, in another possible world – which would be the global correlate of another system of experience –, perceptual acts, can these acts then be different from what we described as being the "essence" of perception? And it is answered, of course, that they cannot, because if we have called perception acts of *that type*, then, if there is perception in another world, then there must be acts (and objects) of that type.

However, the question is not to know whether, there being perception, the perception would be like ours, but if it is possible that there are *other forms and other completely diverse types* of acquaintance with a surrounding world, the form of which is, *in this actual world of ours*, what we rigidly designated as "perception". If we could scrutinize all possible forms by which a knowing system makes

acquaintance with its surrounding world, that would be, indeed, a true synthetic *a priori* knowledge. But obviously we cannot.

Mutatis mutandis, the same can be understood, perhaps even better, in the case of a measuring unit. Let's stipulate, in the manner of Reichenbach, that "meter" means the ten-millionth part of the quadrant of an Earth meridian; let's now say, in the manner of Kripke, that "meter" rigidly designates the length of the platinum prototype kept in the International Office of Weights and Measures. If we then ask: what does the name "meter" mean in another possible world?, the only answer is that, if "meter" designates that platinum slab, then in other possible world, if the *same* name exists, then it can only designate the *same* object (because otherwise it would not be the same name, but a different name with an identical word). However, what would be interesting to know would be if *in any possible world* it is necessary for *this* meter to be the basic measuring unit, and the answer to that question is clearly *no* – it could be *any other*. Suppose that Earth has another size, or that there is no Earth at all. The question is not about knowing whether it is necessary that a meter is a meter; rather, the question is about knowing if it is possible that there are other possible units besides the meter that fulfill the same function the meter fulfills for us, in our actual world.

All in all, Phenomenology's synthetic *a priori* knowledge is based on this trickery: the stipulation and creation of rigid denominators, along with their exportation to all possible worlds. But the question is not to know whether, in a counter-factual world, if there were perceptions, they would have the same essential type as ours, that is, if it is necessary that perceptions are perceptions; the productive question is rather whether, in a counter-factual world, there can be something else in place of what we call "perception", and *what*. Phenomenology robs the opportunity for this question. Its putative synthetic-material *a priori* knowledge is, in the end, something quite narrow: it consists in the rash universalization of properties native to the *contingent* objects of our actual experience. At most, its so called essential "laws" –which, when bared, reveal themselves to be a fusion of meaning stipulations (in themselves arbitrary) and of rigidifications of references for names– express an *a posteriori* necessity and not an effective synthetic *a priori* knowledge.

I'll address the second question quickly (it is too important and too complex). Whether Descartes is or is not really the one responsible (and I believe not...), everything stands as if the theory of knowledge, in modernity, had lived in the assumption that the subject of knowledge only has direct access to his internal states and that, so that, based on these states, the subject represents a so-called "exterior" world. In the doctrine of empiricism, the most basic internal states have been identified with *sense data*, that is, with the sensorial impressions (internal

and external). From this situation arose the modern problem of knowing whether we are certain or not of an objective world "outside" (meaning, independent) of our "representations". Berkeley replied famously that there was no such material universe. This modern account of knowledge is, however, in my opinion, a fiction. A sensory organ does not register internal states that would supposedly correspond to an inaccessible "external" reality. An organ is a generator of interactions that creates not an "internal representation" of an "external world", but a collection of connected events which constitute the world at that "scale". For example, the system eye-brain-consciousness is the only device by means of which a colorful world can appear, in the same way that the ear-brain system is a device in which a sonorous world appears. These worlds – sonorous and colorful – are not internal to the subject – they are a scale of reality that is produced by the interaction of the surrounding world with the sensory apparatus. In this way, sensible objects are not "representations in me" of an "external thing", as modern subjectivism says. They are the *world itself* to the scale of the interaction devices we have. Had we other interaction devices, for example, a sonar or a sensitivity to Earth's magnetic field, there would be then another *scale of reality*. There can be countless devices, be they natural or artificial. Let's suppose an organism was built around a Geiger-Müller counter. This organism would live, know and situate itself in a world of gamma radiations, X-rays, alpha and beta particles. That would be its *scale of reality*. All Physics instruments must be understood as *such* as "sensorialization" apparatuses; in this case, ones which do not have consciousness, but are connected to the consciousness of a human observer through the transposition of the states-of-things of the apparatuses to states-of-things of that observer's P-experience (for instance: a certain nuclear composition is "transcribed" into a series of black and colored stripes, a "specter" visually detectable in the observer's P-experience).

If we are persuaded of these ideas, we will understand the deep reason for transcendentalism (Kant's and Husserl's): there is only a world *for* a consciousness, that is, in my rendering: there are only objects for a system of devices that configure a scale of reality. But we also understand transcendentalism's false step: from the fact that there is only a world for a consciousness does not follow that there is only one form of consciousness and one form of world, that is, a single scale of reality – on the contrary, what the theory of knowledge has called "consciousness" and "subject" should be understood as a collection of devices that sensorially configure a world at a certain scale. A subject is never an instance of a pure "representation" of reality; the subject is an active knowledge and reaction device interacting with the entities of his scale.

Having briefly said this, I'll turn to the last question. I'll start by extracting a

consequence from what was said. It's the following: at the scale of reality that our categorical-sensory apparatus configures, we discriminate bodies in movement in space and time, and that is not an illusion – on the contrary, that is a *fact* of the world at this scale.

The representation of time and space is anchored in perception. It is because we believe in the perceptive image of the world that we believe that there are bodies, and that there is a space where the bodies are localized, and that there is a time through which bodies last. We believe, according to T-experience's idealizations, that space is a tridimensional continuous multiplicity that extends limitlessly, and that time is a one-dimensional continuous multiplicity, split in a present, a past and a future. In this manner, we project a vision of the world as a whole that "has" a past, and is "going" towards a future, in which only the infinitesimal moment of "now" is real each time. The continuity of time is grounded on the continuity of the consciousness of time, on the unity of the flux of consciousness. The unlimitedness of space is grounded on the consciousness of the mobility of the lived body. Vision affords to the tridimensional property of physical space. It is this "psychological" basis of the concept-formation of space and time that is transposed into the image of the world and objectified, i.e., disconnected both from its subjective conditions of production and from its roots in a sensory apparatus.

However, can space and time be thought *objectively*, that is, disconnected from the sensory apparatus which supports them – and *roots* them – in P-experience?

We understand time as a flux. This is a vision of time as a whole from the point of view of a point of actuality called the "now". Moreover, for there to be time, there must be infinitesimal points called "instants". In addition, in order to connect the fluxional dimension to the quantitative dimension, each instant should correspond to a "now" or, in other words, each of time's instants must be able to be, for once, an *actual* "now". An instant that could not be, had not been, or would not be in the now-point of actuality would precisely not be an instant of time. The very notion of instant, when thought objectively, is already, in itself, a baffling old problem: indeed, how can time be composed of units without duration? That old problem is not, however, what is most important here. The difficult point in this common understanding of time is that time is *simultaneously* thought of as a total series of instants connected by an order relation (like the series of numbers, in which all numbers are simultaneously present), *and* as going through a now-point, which is something like a fixed point, which is distinguished from the series of instants, and which places a portion of that series in an area called "past", and another portion in an area called "future". It's as if time was, simultaneously, a rigid and static series of present instants linked by an order relation, and a torrent which would flow through the now-point of actuality. Strangely enough, time *is* and time

passes.

Now, what I say –following McTaggart but in order to reach different conclusions– is that the past-present-future structure *is not* objectifiable, that is, thinkable without a subject and a subjective stream of experience; and that time as a rigid series of instants, if it is objectifiable –and it is controversial whether it is or not– would not be, however, *time* in the sense of something that flows, that passes and where something like the phenomena of change happens. In a word, the passage of time (the very source of the perception of change) would be a "subjective datum", and objective time would be an immobile series. This breaks apart the representation of time.

Let's look at it. The solidarity between the now and an observer is easy to understand. Let's imagine the series of instants. Each instant has another instant immediately before it, and another instant immediately after it, and so on. These relations are *order* relations; they are fixed and cannot change: an instant can't change its position with another instant – it is either before or after it, and it will be so forever. The series of instants is, as I said, fixed and rigid. Moreover, none of the instants is a *now*. Each one has a position in relation to the others. But we cannot say of any of them that it is *actual*, while the others are past (*already not* now) or future (*still not* now). For that, it would be necessary to imagine a flow and a passage of each instant through an actuality point; but the series of instants does not have such a passage, it is a fixed and rigid series. For there to be a "now", it is necessary that there is an observer to open a viewpoint on time, similar to the "here", which is a viewpoint on space. And that point of view on time consists of, let's say, a "window of actuality", an ever-lasting source-point of "now", with a tail of memory and a horizon of expectation. In fact, without memory (retention of what "was") and expectation (anticipation of what "will be") there is no *flow* of time. It is in relation to now that there is a past and a future, and a movement from the future to the past, and this now is located not in the series of instants, but in the observer's position. Each instant switches its temporal predicates in relation to the now-point: it is future, then present, then past. If we eliminated the subjective experience of time – the observer's point of view, based on expectation and memory – we would be left with an immobile series, where all instants simultaneously *are*. That is what we could think objectively of time, but time like such a fixed series *is not* what we call "time". Time, thought "objectively" (without its root in the observer's P-experience), therefore, results in the more fundamental concept of a multiplicity of positions structured by an order relation, that is, results in a pure logical-mathematical entity.

The same reflection is valid for space and its relation to a "here", the orientating point of view from which the three directions are structured (left-right, front-back,

above-below) and on the basis of which the "dimensions" of space are constituted. I will not repeat the argument, which is similar to the former in every respect. I will say only, about *objective* space, disconnected from the reference to the observer and, therefore, from a "here", zero-point of orientation, that this space of "non-extended points" suffers from two serious drawbacks: first, *it has no orientation*; second, *it is insufficient for thinking physical nature*. I will say nothing about space's lack of orientation because the idea that we can arbitrarily take any point to draw axes of reference means exactly that space, "in itself", lacks intrinsic orientation. But the already widespread idea that the characterization of the physical universe involved the idea of a multiplicity of matter juxtaposed in space, coexisting in a simultaneity plane, is profoundly paradoxical when we look at it closer. Because to claim the existence of physical bodies next to each other, coexisting and distributed across space is, in the end, tantamount to denying any interaction between those bodies. In fact, a body which coexists next to another in the same instant, however close the proximity, *does not interact with that other* because no signal has an infinite propagation speed that would allow the instantaneous interaction between them. Therefore, that classic idea of a space filled with matter in coexistence (Descartes), or partially full of matter in each instant of universal time (Newton) is an idea which fosters a profound paradox: that definition of a cosmic whole is exactly the denial of physical interaction. All interactions are, in fact, coincidences in space and time. The juxtaposition of matter throughout space is the very definition of the absence of relation.

In this way, matter in space taken objectively, without relation to the orientation in P-experience, leads to the concept of an absence of interaction between physical systems. This concept is no longer a concept of "space", but a concept of a more fundamental relation. Two things are said to be "distant" in space, and more or less distant to the extent that the interaction between them is more or less effective. Two systems in full interaction are said to coincide. Two systems without interaction are said to be coexisting in juxtaposition. And the distance will measure, here, the more or less remote character of a possible interaction.

6.5 Some theses by way of conclusion

I will say, in summary, the following:

1. The representation of a material spatial-temporal universe is an idealization based on perceptive experience.

2. That idealization has a local validity for the Physics that deals with macro-

scopic masses (=bodies, at the observer's scale) in movement; it gradually loses its relevance when it's transposed to other dimensions inaccessible to P-experience (namely, quantum phenomena and, at its base, the sub-quantum world).

3. The concepts of space and time, when thought objectively without reference to P-experience, are reduced to more fundamental concepts, in such a way that the "relation of time" and "relation of space" acquire a different meaning: they are order and interaction relations.
4. Nature and natural being do not mean space-time with matter in movement; rather, they mean process of self-organization and organized being.
5. An organized being has a "form", that is, a pattern or structure that can be known, and there are only beings to the extent that there are such forms.
6. Nature is a system of forms.
7. The properties of a natural being emerge in a complex whole that can't be analyzed in simple elements: the properties arising in it and are the ground for other subsequent forms, and so on.
8. An organized being has an "internal history", that is, a process of self-development in such a way that it is not only at a point in time, but rather it *is* the ensemble of its complete unfolding, according to its form.
9. The development according to a form is becoming. Forms are not perpetual essences, but variable patterns of a self-structuring of matter in systems maintaining stability.
10. In the new Physics, the primordial form is the emergent *acron* in the sub-quantum medium.
11. We could call, platonically, *chora* the ultimate "place" where these acronic forms emerge, which is not the geometrical space of the moderns, but the *where* each being emerges or, better said, *the place created by the very emergence of being.*
12. And we could call *kairos* the occasion in which these forms emerge, their appropriate or adequate moment, which is not measurable time, *chronos*, but the *moment created by the very emergence of being.*

Chapter 7

Simultaneity Concepts in Physics

Amaro Rica da Silva
CENTRA - Instituto Superior Técnico, Physics Dept.
Av. Rovisco Pais 1, Lisbon Codex 1049-001, Portugal
(ricadasilva@ist.utl.pt)

Summary: Simultaneity concepts are crucial in physics, and often taken for granted. How should/could we define simultaneity ? Is there a well defined "now" moment far away from the immediate vicinity of an observer? We show here that in the strict context of speed invariance of light for all observers, simple collisions between two bodies cannot be detailed, and only asymptotical statements can be made. Furthermore, time-dilation relations are shown to depend not only on the relative speed of the observers, but also on other geometrical relations between them.

Keywords: Simultaneity, collisions, relativity, special.

7.1 Observers and Physical Parametrization

The mathematical concept of manifold and dimension can be easily adopted as a description of the key properties of observers of physical space. A set of pairs $(\mathcal{U}_\alpha, \eta_\alpha)$ where $\eta_\alpha : \mathcal{U}_\alpha \to \Re^n$ may establish a correspondence between some physical space 'event' and n real parameters resulting from the α-observer's measurements. Topologically, $\mathcal{U}_\alpha$ defines (or is defined by) the vicinity of the α-observer. The set of transition functions $\eta_{\alpha\beta} = \eta_\alpha \circ \eta_\beta^{-1} \in Aut(\Re^n)$ constitutes a dictionary with which neighboring observers may compare their measurements of the 'same event'. The key here is the word 'same'. For non-neighboring observers, the question arises as to what is that. Hence the idea of creating some sort of measuring device that could be locally synchronized and sent with the observers to distant locations so that they could identify sameness in events when comparing their measurements. The proper notion of "local measurement" can be questioned also, but at the classical level we will assume that it can be well defined.

What are then the assumptions needed to use simultaneity concepts in physics? At least one must be able to locally create synchronized clocks that can be sent to faraway locations (although that is highly impractical and seldom done) and that their frequencies be kept invariant when displaced, and that distances may be measured and kept in time. On the practical side what is often used is a tacit agreement that certain physical phenomena (such as the decay frequency of certain processes) may be invariant when observed locally in certain conditions by different observers at faraway locations.

Why is it so important to have a coherent simultaneity concept in physics? A simple but crucial example is the basic mechanics of a pair of particles interacting through some means, typically a gravitational or electrical 'force'. If simultaneity cannot be defined absolutely when the particles are apart, then concepts such as center of mass, total momentum and angular momentum, kinetic and potential energy of the system cease to make sense at each instant, and thus there is no way to parametrize trajectories of these particles without introducing some very strange artifacts such as virtual particles interacting instantly and traveling to the past.[4]

7.1.1 Simultaneity in Classical Physics

There is no limit to the size of measurements in classical physics, hence reference systems are commonly built in arbitrarily large scales by establishing an isometry with the Euclidean metric in $\mathbb{R}^n$. Time and space are deemed global concepts, however

the question of weather the mathematical "instant" is uniquely related to the physical one is still relevant. Assuming instantaneous interactions the question seems to be resolved, but for finite speed interactions at a maximum speed c there is a problem.

The observation of events at distinct points $\mathcal{P}_1$ and $\mathcal{P}_2$, simultaneous at time t as measured by an observer $\mathcal{O}$ while at $\mathcal{P}_o(t)$, with $\mathcal{P}_1$ e $\mathcal{P}_2$ at a distance d_1 and d_2 from $\mathcal{P}_o(t)$, corresponds to events that would occur at different local times if clocks at $\mathcal{P}_1$ and $\mathcal{P}_2$ had been synchronized at some point with that at $\mathcal{P}_o$ and kept the same frequency. In a linear parametrization of "space" an observer would make a correspondence of $\mathcal{P}_1$ and $\mathcal{P}_2$ with vectors

$$\begin{cases} \vec{\mathbf{r}}_1(t) = \mathcal{P}_1\left(t - \dfrac{d_1}{c}\right) - \mathcal{P}_o(t) \\ \\ \vec{\mathbf{r}}_2(t) = \mathcal{P}_2\left(t - \dfrac{d_2}{c}\right) - \mathcal{P}_o(t) \end{cases} \Longrightarrow \begin{cases} \mathcal{P}_1(\tau) = \mathcal{P}_o\left(\tau + \dfrac{d_1}{c}\right) + \vec{\mathbf{r}}_1\left(\tau + \dfrac{d_1}{c}\right) \\ \\ \mathcal{P}_2(\tau) = \mathcal{P}_o\left(\tau + \dfrac{d_2}{c}\right) + \vec{\mathbf{r}}_2\left(\tau + \dfrac{d_2}{c}\right) \end{cases} \tag{7.1}$$

In the case that $\mathcal{P}$ has a variable distance to the observer $\mathcal{O}$, its observation from $\mathcal{P}_o(t)$ would correspond to the definition of a relative velocity

$$\begin{cases} \vec{\mathbf{r}}(t) & = \mathcal{P}\left(t - \dfrac{d(t)}{c}\right) - \mathcal{P}_o(t) \\ \\ \vec{\mathbf{r}}(t+\delta t) & = \mathcal{P}\left(t + \delta t - \dfrac{d(t+\delta t)}{c}\right) - \mathcal{P}_o(t+\delta t) \end{cases} \Longrightarrow$$

$$\begin{aligned} \vec{\mathbf{v}}(t) &= \lim_{\delta t \to 0}\left(\frac{\vec{\mathbf{r}}(t+\delta t) - \vec{\mathbf{r}}(t)}{\delta t}\right) = \\ \\ &= \lim_{\delta t \to 0}\left(\frac{\mathcal{P}\left(t + \delta t - \dfrac{d(t+\delta t)}{c}\right) - \mathcal{P}\left(t - \dfrac{d(t)}{c}\right)}{\delta t} - \frac{\mathcal{P}_o(t+\delta t) - \mathcal{P}_o(t)}{\delta t}\right) \end{aligned}$$

$$\begin{aligned}\vec{\mathbf{v}}(t) &= \lim_{\delta t \to 0} \left(\frac{\mathcal{P}\left(t + \delta t - \frac{d(t)}{c} - \frac{\dot{r}(t)}{c}\delta t\right) - \mathcal{P}\left(t - \frac{d(t)}{c}\right)}{\delta t} \right) - \vec{\mathbf{V}}_o(t) = \\ &= \vec{\mathbf{v}}'\left(t - \frac{d(t)}{c}\right) - \vec{\mathbf{V}}_o(t) - \frac{\dot{r}(t)}{c}\frac{d\mathcal{P}(\tau)}{d\tau}\bigg|_{t-\frac{d(t)}{c}} = \\ &= \left(1 - \frac{\dot{r}(t)}{c}\right)\vec{\mathbf{v}}'\left(t - \frac{d(t)}{c}\right) - \vec{\mathbf{V}}_o(t)\end{aligned} \tag{7.2}$$

Notice that if $\dot{r}(t) = c$ then $\vec{\mathbf{v}}(t) = -\vec{\mathbf{V}}_o(t)$ that is, $\mathcal{P}$ is receding from its initial position at speed c in a radial direction relative to $\mathcal{P}_o$.

7.1.2 Simultaneity in Relativistic Physics

In relativistic physics one assumes that local "inertial" reference frames can be built in the neighborhood of non-rotating, free-falling observers. This means a local isometry of space time parametrizations with $\Re^4$ endowed with a Minkowsky metric. A projection of this metric over a "slice of simultaneity" yields an Euclidean spatial metric in a Einsteinian $3+1$ interpretation of space and time.

Thus in relativistic physics absolute space and time are now substituted by the invariance of the speed of light and the invariance of the line element

$$ds^2 = c^2dt^2 - d\vec{\mathbf{r}}^2$$

assuming also from the start that there is the possibility of **Clock Synchronization** and the **Isotropy of the speed of light**.

The inability of these conventions to combine multiple observers in non-inertial frames (the Einstein convention is unusable for rotating systems for instance) make it clear that it is impossible to avoid arbitrariness in the choice of extended synchronization.

In the last few decades, in particular due to discussions involving experiments that question the **isotropy** of the speed of light[3], there has been a rising need to show the independence of the relativistic formulation from this particular simultaneity convention.

Recently [1] in 2002, Minguzzi has shown that the causal structure of the Minkowski interpretation could be derived solely from the invariance of the speed of light in closed circuits, thus suggesting a strategy to use only measurements that do not depend on the Synchronization Convention.

In **General Relativity** already there are similarities between **Conventioned Simultaneity** and **Gauge Theory** that can be applied to the notion of stationary reference systems in contexts such as **rotating platforms** in Special Relativity or **Kerr metrics** (a generalization of the Schwarschild solution to a spherical rotating body) in General Relativity.

7.1.3 Simultaneity in Quantum Physics

In Quantum Mechanics the treatment of the time variable is privileged and non-quantizable. Simultaneity is not questioned, and even recent developments on entanglement and non-locality strongly supports the notion of absolute space and time.

Fock and then Stueckelberg introduced explicitly evolution parameters into Relativistic Quantum Mechanics and end up using two time variables: a time coordinate in the Einsteinian sense and an invariant, Newtonian scalar parameter in order to describe space-time evolution (Relativistic Dynamics). This distinction allows the use of a universal time direction together with a time parameter for which evolution to the past is as valid as to the future.

7.1.4 Simultaneity in Astrophysics and Cosmology

At the astrophysical scales our perspective of the Universe will be necessarily deformed by temporal deviations assuming that all our observation methods are based on electromagnetic measurements. Our measures of distance are fundamentally based on assumptions about the nature of radiation, models of Type Ia Supernovae, the Doppler effect...

Some theoretical models try to deduce the existence of dark matter regions through the use of a putative gravitational lensing effect. There are however recent studies that show that light propagation in moving media does have an effect on the shape of the emission sources. Weak gravitational lensing uses statistical hypothesis about the "average" shape of galaxies to determine their supposed deformations.

7.2 What are the implications of using different simultaneity notions?

Action-Reaction Principle is no longer valid in Special Relativity, and it has to be generalized in Classical Electromagnetism. Also variational principles and instantaneous action-at-a-distance have to be reassessed.[2][6]

7.2.1 Relativistic Systems of Particles

The assumption of absolute simultaneity in classical physics allows for the definition of certain constructs such as Center of Mass and total Momenta for systems of particles. These concepts do not easily translate to useful quantities when simultaneity is dependent on an observer's state of motion.

Synge[5] uses the concept of elementary impulses to define relativistic Angular Momenta and Center-of-Mass.

"The world-lines of particles and impulses will consist of straight portions between collisions of particles with elementary impulses, with sudden changes of direction at these collisions".

This is done at the expense of accepting that collisions are now instantaneous and point-like, in which case conservation of some Energy-Momenta 4-vector $\mathcal{P}$ can now be envisioned. The relativistic Angular Momentum $\mathcal{L}(\xi)$ relative to some space-time event ξ can thus be defined in the usual way, in which case the Center-of-Mass world-line is defined as the set of events ξ for which $\mathcal{L}(\xi) \cdot \mathcal{P} = 0$.[4]

In fact, let us consider a (special)-relativistic change of reference frame, using the standard Lorentz transformations:

$$\begin{cases} \vec{\mathbf{r}}' = \vec{\mathbf{r}}^{\perp} + \gamma(V)(\vec{\mathbf{r}}^{\parallel} - \vec{\mathbf{V}}t) \\ \\ t' = \gamma(V)(t - \frac{1}{c^2}\vec{\mathbf{r}} \cdot \vec{\mathbf{V}}) \end{cases} \quad \text{where} \quad \begin{cases} \vec{\mathbf{r}}^{\perp} = \dfrac{\vec{\mathbf{V}} \times \left(\vec{\mathbf{r}} \times \vec{\mathbf{V}}\right)}{V^2} = \vec{\mathbf{r}} - \vec{\mathbf{r}}^{\parallel} \\ \\ \vec{\mathbf{r}}^{\parallel} = \dfrac{\left(\vec{\mathbf{r}} \cdot \vec{\mathbf{V}}\right)}{V^2}\,\vec{\mathbf{V}} \end{cases} \tag{7.3}$$

with $\gamma(V) = \frac{1}{\sqrt{1-\left(\frac{V}{c}\right)^2}}$, where $\vec{\mathbf{V}}$ stands for the relative velocity of the reference frames, and $\perp$ or $\parallel$ refer to vector components perpendicular to, or in the direction of $\vec{\mathbf{V}}$. For the observers in the primed frame, a time τ' references different times t_1

and t_2 as seen by the unprimed observers at different positions $\vec{\mathbf{r}}_1$ and $\vec{\mathbf{r}}_2$ since

$$\tau' = \gamma(V)\left(t_1 - \frac{\vec{\mathbf{r}}_1 \cdot \vec{\mathbf{V}}}{c^2}\right) = \left(t_2 - \frac{\vec{\mathbf{r}}_2 \cdot \vec{\mathbf{V}}}{c^2}\right) \tag{7.4}$$

Thus, what is a conventional Center-of-Mass $\vec{\mathbf{R}}'_{cm}(\tau')$ for a two-particle collision for the primed observer is in fact the result of a transformation of quantities which for the unprimed observer are measured at different times and which cannot be related to any definition of a Center-of-Mass in the unprimed frame (notice $\vec{\mathbf{r}}_1(t_1)$ and $\vec{\mathbf{r}}_2(t_2)$ in the next formula).

$$\begin{aligned}\vec{\mathbf{R}}'_{cm}(\tau') &= \frac{m_1\vec{\mathbf{r}}'_1(\tau') + m_2\vec{\mathbf{r}}'_2(\tau')}{m_1+m_2} = \\ &= \frac{m_1\vec{\mathbf{r}}_1^{\perp}(t_1) + m_2\vec{\mathbf{r}}_2^{\perp}(t_2)}{m_1+m_2} + \gamma(v)\left(\frac{m_1\vec{\mathbf{r}}_1^{\parallel}(t_1) + m_2\vec{\mathbf{r}}_2^{\parallel}(t_2)}{m_1+m_2} - \frac{(m_1t_1+m_2t_2)}{m_1+m_2}\vec{\mathbf{V}}\right)\end{aligned} \tag{7.5}$$

We would be equally unable to define a Center-of-Mass velocity for the same reasons, since now

$$\vec{\mathbf{v}}'_1(\tau') = \frac{d\vec{\mathbf{r}}'_1(\tau')}{d\tau'} = \frac{d\vec{\mathbf{r}}'_1(\tau')}{dt_1}\,\frac{dt_1}{d\tau'} =$$

$$= \left(\frac{d\vec{\mathbf{r}}_1^{\perp}}{dt} + \gamma(V)\left(\frac{d\vec{\mathbf{r}}_1^{\parallel}}{dt_1} - \vec{\mathbf{V}}\right)\right)\frac{1}{\frac{d\tau'}{dt_1}} =$$

$$= \frac{\vec{\mathbf{v}}_1^{\perp}(t_1)}{\gamma(V)\left(1 - \frac{\vec{\mathbf{V}}.\vec{\mathbf{v}}_1(t_1)}{c^2}\right)} + \frac{\vec{\mathbf{v}}_1^{\parallel}(t_1) - \vec{\mathbf{V}}}{1 - \frac{\vec{\mathbf{V}}.\vec{\mathbf{v}}_1(t_1)}{c^2}} \tag{7.6}$$

and

$$\vec{\mathbf{v}}_1^{\perp} = \frac{\vec{\mathbf{V}} \times \left(\vec{\mathbf{v}}_1 \times \vec{\mathbf{V}}\right)}{V^2} \quad ; \quad \vec{\mathbf{v}}_1^{\parallel} = \frac{\left(\vec{\mathbf{V}} \cdot \vec{\mathbf{v}}_1\right)}{V^2}\vec{\mathbf{V}} \tag{7.7}$$

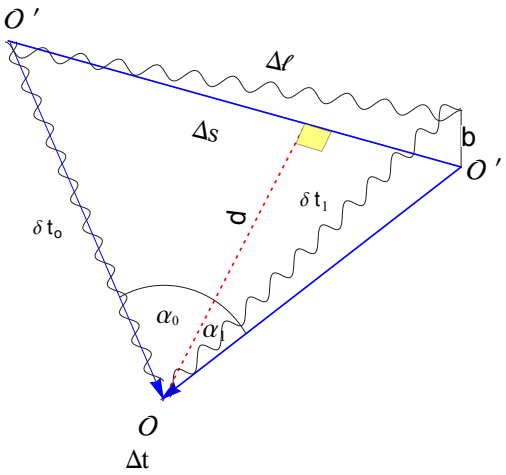
Similar reasoning leads to

$$\vec{\mathbf{v}}'_1(\tau') = \frac{\vec{\mathbf{v}}_2^{\perp}(t_2)}{\gamma(V)\left(1 - \frac{\vec{\mathbf{V}}.\vec{\mathbf{v}}_2(t_2)}{c^2}\right)} + \frac{\vec{\mathbf{v}}_2^{\parallel}(t_2) - \vec{\mathbf{V}}}{1 - \frac{\vec{\mathbf{V}}.\vec{\mathbf{v}}_1(t_2)}{c^2}} \tag{7.8}$$

and thus what passes for $\vec{\mathbf{V}}'_{cm}(\tau')$ is an even more complex combination of velocities of each particle measured at different times by the unprimed observers.

Thus what is usually done in relativistic collisions is to consider the conservation of the four-vector energy-momentum asymptotically, that is when the particles are no longer interacting, and no attempt can be made to describe in detail what happens during the interaction.

7.3 Local Measures of Remote Events



An observer $\mathcal{O}$ records a time interval Δt after receiving a light pulse originally emitted by an observer $\mathcal{O}'$, coming from an azimuth α_o until a subsequent light pulse coming from an azimuth α_1. Assuming that the distance from $\mathcal{O}$ to the straight line trajectory of $\mathcal{O}'$ is d, its possible to determine the distance Δs that $\mathcal{O}'$ travels in the rest frame of $\mathcal{O}$ during that time, an thus also its velocity V_c. We assume here that the light pulses are emitted by a clock that was moving with $\mathcal{O}'$, with detector/emitter separated by a distance b orthogonal to the plane formed by $\mathcal{O}$ and the speed V_c.

We shall assume that the light trajectory is rectilinear and the geometry of space between $\mathcal{O}$ and $\mathcal{O}'$ is Euclidean.

The above scenario has its limitations: for one, how does one change the calculation if the space-time geometry is given through a non-flat metric $g_{ij}(\vec{\mathbf{r}})$ and thus the light pulse trajectory is a geodesic? Also, in such a case how does the distance

traveled relates to local measures by $\mathcal{O}$. Distance d is assumed known, but that is not the case in general, so how do errors in the estimation of d affect the ensuing calculations?

Assuming then the aforementioned caveats, the distance traveled by $\mathcal{O}'$ during a time-lapse Δt in $\mathcal{S}_{\mathcal{O}}$ reference frame is

$$\Delta s = d\left(\tan\left(\alpha_o\right) - \tan\left(\alpha_1\right)\right) \tag{7.9}$$

Since the initial light pulse will arrive at $\mathcal{O}$ after a time

$$\delta t_o = \frac{d}{c}\sec\left(\alpha_o\right) \tag{7.10}$$

an the final light pulse will arrive at $\mathcal{O}$ after a time

$$\delta t_1 = \frac{\sqrt{b^2 + d^2\sec^2\left(\alpha_1\right)}}{c} \tag{7.11}$$

then the time-of-flight of the clock in frame $\mathcal{S}_{\mathcal{O}}$ should be

$$\Delta t_c = \Delta t - \delta t_1 + \delta t_o = \frac{d\sec\left(\alpha_o\right) - \sqrt{b^2 + d^2\sec^2\left(\alpha_1\right)}}{c} + \Delta t \tag{7.12}$$

where Δt is the total time measured by $\mathcal{O}$ between arrival of both signals.

In the clock's frame $\mathcal{O}'$, the time $\Delta t'$ measured by $\mathcal{O}'$ between emission and reception of a pulse traveling a small distance b is

$$\Delta t' = \frac{b}{c} \tag{7.13}$$

We should note that from this we get the relation between time measurements by both observers. Again one might object that without the use clocks based on distance traveled by a light pulse but instead, for instance, based on characteristic frequencies of certain atomic decays a different relation might result. Also this relation is valid strictly only in the case of uniform motion of $\mathcal{O}'$ in $\mathcal{S}_{\mathcal{O}}$.

From the above we infer the clock speed as seen by $\mathcal{O}$

$$V_c = \frac{\Delta s}{\Delta t_c} = \frac{d\left(\tan\left(\alpha_o\right) - \tan\left(\alpha_1\right)\right)}{\Delta t + \frac{1}{c}\left(d\sec\left(\alpha_o\right) - \sqrt{b^2 + d^2\sec^2\left(\alpha_1\right)}\right)} \tag{7.14}$$

Assuming now that a light pulse is used in the workings of $\mathcal{O}'$'s clock, we deduce that the distance $\Delta\ell$ traveled by this pulse in $\mathcal{S}_{\mathcal{O}}$ is

$$\Delta\ell = c\,\Delta t_c = c\,\Delta t - \sqrt{b^2 + d^2\sec^2(\alpha_1)} + d\sec(\alpha_o) \tag{7.15}$$

In the $\mathcal{S}_{\mathcal{O}}$ frame the distances are related as

$$\Delta\ell^2 = b^2 + \Delta s^2 \tag{7.16}$$

Since we are assuming that $\mathcal{O}'$ is traveling with constant velocity V_c in $\mathcal{S}_{\mathcal{O}}$, we can obtain the Lorentz factor for the time "dilation" near the clock from a purely Cartesian relation between $\Delta\ell$, Δs and b in this privileged orientation. If the clock's pulse did not travel in a orthogonal direction to the plane of motion going through $\mathcal{O}$ then additional calculations would be necessary and Lorentz dilation could look different.

$$\Delta\ell^2 = b^2 + \Delta s^2 \quad \Longrightarrow \quad (c\,\Delta t_c)^2 = (c\,\Delta t')^2 + (V_c\,\Delta t_c)^2 \tag{7.17}$$

and thus

$$\Delta t' = \Delta t_c\sqrt{1 - \frac{V_c^2}{c^2}} \tag{7.18}$$

From this setup we conclude that the relation between "proper" time $\Delta t'$ measured by $\mathcal{O}'$ and the time Δt measured by $\mathcal{O}$ must evidently depend on the distance and position of $\mathcal{O}$ relative to the trajectory of $\mathcal{O}'$.

From the previous relations we can deduce that

$$c\Delta t + d\sec(\alpha_o) = \frac{c\Delta t'}{\sqrt{1 - \frac{V_c^2}{c^2}}} + \sqrt{d^2\sec^2(\alpha_1) + c^2(\Delta t')^2} \tag{7.19}$$

Assuming $\alpha_o \approx \alpha_1$ and the initial distance between $\mathcal{O}$ and $\mathcal{O}'$ as r then

$$\Delta t = \frac{\Delta t'}{\sqrt{1 - \frac{V_c^2}{c^2}}}\left(1 - \frac{\sin(\alpha_o)\,V_c}{c\sqrt{1 + \frac{(\Delta t')^2}{\left(\frac{r}{c}\right)^2}}}\right) + \frac{r}{c}\left(-1 + \sqrt{1 + \frac{(\Delta t')^2}{\left(\frac{r}{c}\right)^2}}\right) \tag{7.20}$$

If $(\Delta t')^2 \ll \left(\frac{r}{c}\right)^2$ then

$$\Delta t \approx \frac{\Delta t'}{\sqrt{1 - \frac{V_c^2}{c^2}}}\left(1 - \frac{V_c}{c}\sin(\alpha_o)\right) \tag{7.21}$$

The situation where $\alpha_o = \pm\frac{\pi}{2}$ never happens as it would mean observing $\mathcal{O}'$ from an infinite distance. On the other hand, when $\alpha_o = 0$ the first pulse is emitted

just as $\mathcal{O}'$ is closest to $\mathcal{O}$. In this case, when $\frac{r}{c} \ll \Delta t' = \frac{b}{c}$ then we have

$$\Delta t \approx \Delta t' \left(\frac{1}{\sqrt{1 - \frac{V_c^2}{c^2}}} + 1 \right) \tag{7.22}$$

whereas if $\frac{r}{c} \gg \Delta t' = \frac{b}{c}$ we get the traditional

$$\Delta t \approx \frac{\Delta t'}{\sqrt{1 - \frac{V_c^2}{c^2}}} \tag{7.23}$$

Bibliography

[1] E. Minguzzi. Simultaneity and generalized connections in general relativity. *Classical and Quantum Gravity*, 20(11):2443, 2003.

[2] L. Page and N.I. Adams Jr. Action and reaction between moving charges. *American Journal of Physics*, 13:141, 1945.

[3] E. J. Post. Sagnac effect. *Reviews of Modern Physics*, 39(2):475, 1967.

[4] J. L Synge. Angular momentum, mass-center and the inverse square law in special relativity. *Phys. Rev.*, 47(10):760–767, May 1935.

[5] J.L. Synge. *Relativity: the special theory*. Number v. 2 in Series in physics. North-Holland, 1958.

[6] J.A. Wheeler and R.P. Feynman. Classical electrodynamics in terms of direct interparticle action. *Reviews of Modern Physics*, 21(3):425, 1949.

Chapter 8

The Bergsonian intuition of duration: the time of science is space

Magda Costa Carvalho
D.H.F.C.S.
Universidade dos Açores
9500 Ponta Delgada
and
Centro de Filosofia da Universidade de Lisboa, Portugal
(magdac@uac.pt)

8.1 Abstract

According to Bergson, the philosophical tradition had been unanimous in declaring the question of time essential. However, it had neglected its correct framing[1] which, for the author, lies in the metaphysical approach of an immediate and inner experience of concrete duration.

In the current paper, we shall present Henri Bergson's concept of time, particularly the author's critique to the scope scientific discourse has of this concept. Simultaneously, we shall explore the central role of time in the Bergsonian thought, metaphorically understood as *the very stuff of reality*. We shall not, therefore, ex-

[1] DS [2], p. Vi.

plore Bergson's ideas on Physics, but some of the metaphysical consequences that he withdraws from certain physics' concepts or theories[2].

8.2 Science and Philosophy

Invoking Henri Bergson's thought in such a seminar reveals the up-to-datedness of a work whose philosophical obituary was announced several times over the twentieth century. We think that, in spite of the fact that some of his scientific work is outdated, the Bergsonian thought continues to allow for a fecund and profitable dialogue between science and philosophy.

Bergson was a French philosopher who lived from 1859 to 1941, the author of a *corpus* devoted mostly to the concept of time (or *duration*, as he prefers to call it), and who invested most of his education in the study of the sciences of his epoch (from biology to physics). As a product of the second half of the nineteenth century — an epoch which, as we know, was epistemologically prolific —, Bergson understood from the beginning the indispensability of connecting the philosophical activity to the scientific one. That would be the only path to grasp the whole of reality.

Nevertheless, Bergson also criticised the importance given to scientific knowledge by counterpointing the discredit devoted to metaphysics, a position that earned him some discomfiture in posterity. Aware of such unpopularity, a 75-year old Bergson acknowledges in 1934 that:

> "[...] c'est par erreur qu'on ma classé parmi les contempteurs de la science et de l'intelligence; mais peut-être suis-je un peu responsable de cette erreur, car j'ai toujours insisté sur le côté intuition, connaissance de l'esprit par l'esprit, qui me paraissait avoir été négligé par les philosophes, alors que je m'étendais moins sur ce qui était admis par tout le monde pour la connaissance de la matière, pour la science proprement dite, pour l'intelligence. Dès «L'Évolution créatrice», cependant, j'ai exposé tout au long que l'intelligence, tournée vers la matière, pouvait, dans ce domaine, atteindre l'absolu ; j'allais donc aussi loin ici dans le sens intellectualiste que «tout le monde», plus loin même ; je mettais la science plus haut que ne le faisaient et que ne le

[2] A Portuguese version of this text was submitted and approved for publication in *Kairós*, Revista de Filosofia & Ciência 4: 87-104, 2012. Centro de Filosofia das Ciências da Universidade de Lisboa. The author gratefully acknowledges that this paper has been improved by the discussion held with the audience after the talk.

font encore la plupart des savants)."[3]

The confusion had arisen from one of the main propositions of the Bergsonian thought: the intellectual function has for its chief object the unorganized solid, that is, it is designed for action (it operates through solid perceptions and firm concepts so that the subject can place himself or herself in the moving reality that involves him or her). The image used by the author to illustrate this thesis is that of a cinema projector which creates the illusion of movement through the quick running of a set of photographs: for Bergson, movement exists objectively, but intelligence deals with snapshots, closed representations of reality, letting escape what intimately links each of these instants and unifies them in a constant and continuous becoming.

Thus, intelligence does not naturally tend to speculation, and is destined to think about inert matter. All theoretical-speculative type of thought is to Bergson a kind of evolutionary luxury, since it is action that allows us to survive in the environment where we belong. In this context, science is a kind of prolonging of intelligence's usual knowledge, consisting in the perfecting of rigour, of precision and scope of intelligence's common data[4]. Science operates by reducing reality to a sameness capable of a rigorous symbolic translation, hence mathematically founded.

According to Bergson, science should function together with philosophy (metaphysics), which provides it guidance. Philosophy is the inversion of the usual direction of thought[5], reconverting the subject's attention from the useful and pragmatic dimension of reality to the useless region. That is: philosophy breaks with the dynamics of intelligence and science, having as function to promote the knowledge of facts and laws going beyond them to reach their *deeper causes*[6], which is what Bergson refers to in the excerpt quoted as the knowledge "neglected by philosophers", the spiritual or metaphysical level. The philosophical activity rejects, thus, intelligence as a practical faculty and guides itself beyond scientific interpretation – which cuts reality's moving essence into differentiated and external pieces – and strives to apprehend that becoming.

The author would systematize his positions on that subject in the introduction to *La pensée et le mouvant. Essais et conférences*, Bergson's last work, published in 1934.

[3]C [1], p. 1470.

[4]Bergson understands that evolutionarily, the intellectuality of the mind and materiality of things arose from the inversion of the same vital movement by a process of mutual adaptation, cf. EC [3], p. 207.

[5]PM [5], p. 214.

[6]EC [3], p. 195.

There, Bergson refuses the instauration of a hierarchy between science and metaphysics, assuring that both can *touch reality's substance* ("toucher le fond de la réalité")[7]. Science does it on the realm of physical matter, through intelligence's capacity for abstraction and generalisation. From mathematics to biology, including physics and chemistry, science is founded in positive experience and reaches the essence of reality in what concerns its material dimension. Yet philosophy or metaphysics, having as starting point the subject's internal experience (positive also, due to that), reaches a rigorous and precise collection of knowledge about the non-material region of reality. The relationship between both is, then, one of complementarity: science provides metaphysics with elements for the construction of precise perspectives positively founded; philosophy fecundates science and reformulates it, allowing it to advance in the dominion of matter according to the ultimate causes.

Albeit the conciliatory tone of this text, which had in mind to refute some of the objections collected by Bergson's thought over the years, science and metaphysics are landmarks of diverging directions of thought. Never does the author waiver this premise. Science walks towards matter; metaphysics guides itself by the non-material (by the spirit). Now is our job to question, in what concerns time, what each one has to say.

8.3 A philosophy of time

If we wanted to sketch the main premises of a Bergsonian philosophy of time, we could isolate the following topics:

1. time as a substantial reality[8];
2. time as a psychic (*the very stuff of our life*) and ontological (*the very stuff of reality*) phenomenon;

[7] PM [5], p. 33.

[8] The issue of substantialism in Bergson's work can be controversial, given the nuclear role that mobility plays there. In the text *Introduction à la metaphysique*, from 1903 (PM [5], p. 211), Bergson identifies reality with a principle of mobility, that is, in his perspective there are not things made, but things in the making, not states that self-maintain, but changing states. However, this does not mean a de-substantialisation of reality, since Bergson's philosophy does not do without the notion of 'substance'. He considers fundamental what he calls *the persistence of the existences*: reality is change and change is the very substance of things. The fundament of reality, what supports it and intimately involves it, consists in what our inner perception captures, that is, the substantial duration of things. Substance is movement and change and these, in turn, hold a substantial character.

3. time as duration (passage; transit);
4. duration as invention, acting upon the subject's life and upon reality (radical novelty and unpredictability);
5. duration as a privileged part of reality (refusal of the classic premises of Western metaphysics);
6. refusal of time as a measurable quantity, similar to space (refusal of Kantian thought);
7. refusal of an abstract time, not perceived and experienced concretely by the subject.

None of these premises can be deduced only from scientific knowledge, since to Bergson science represents time as a series of consecutive instants, numerically apprehended, which can be reduced to extremities of intervals or of moments, of virtual halts of time's true flow. Once the essence of time is exactly to *pass*, to flow, this means that it can only be apprehended when passing, not when halted. In this case, it is philosophy that can account for this intertwined intimacy of instants and reveal time as continuity, an indistinct interpenetration or qualitative multiplicity.

What is left to science then? Or, in other words, to what do sciences refer when they refer time? To Bergson the answer is clear: they refer to space. Even the most advanced physics theories about time (Einstein's Relativity Theory, at the epoch) would still be to Bergson a translation of space into mathematical (immobile) terms (limited to counting simultaneities between the events and the positions of a mobile on its trajectory).

Let's wander briefly through the genesis of this idea, so that we can follow the author in the discovery (or intuition) of duration as real time.

8.3.1 The intuition of duration

It was Bergson himself who realized the importance of the process of intuition of time as *duration*, having in several occasions told the story of that moment[9].

Around 1883, Bergson was teaching in the countryside (at Clermont-Ferrand) and, due to the PhD thesis he was working on, he devoted himself to the study of the work *First Principles*, by Englishman Herbert Spencer, the important theorist of

[9]The best-known one can be found in the Journal by Ch. Du Bos, in the entry dating of 22nd February, 1922, and is reproduced in the *Œuvres. Édition du Centenaire* [4], pp. 1541-1543.

a scientific law of evolution adaptable, without exception, to the whole of reality. By analysing precisely Spencer's chapter on the notion of time, Bergson recognised the insufficiency of the mathematical and mechanical perspectives, and found it odd to recognise that nothing would be altered in our representation of things if the relation of velocity between the instants symbolised in scientific language changed:

> "Poser qu'un événement se produira au bout d'un temps t, c'est simplement exprimer qu'on aura compté, d'ici là, un nombre t de simultanéités d'un certain genre. Entre les simultanéités se passera tout ce qu'on voudra. Le temps pourrait s'accélérer énormément, et même infiniment: rien ne serait changé pour le mathématicien, pour le physicien, pour l'astronome."[10].

Then, Bergson's suspicions were still vague, he would confess later. What was clear to him was that if everything in the Universe was to happen in an instant, science would not need to change a single comma in its analysis of reality. There seemed to lack, then, to the scientific concept not just the internal dynamics which should characterize time, as mainly its account as invention (*Time is invention or it is nothing at all*, states Bergson[11]). It was then necessary to find a discourse that could find real time, the dynamic and creative force of reality.

The path to follow would come to him during a class on the paradoxes of Zeno of Elea, in which Bergson concluded that the origin of such sophisms lies simply in the confusion between the concepts of movement and of space. In the several paradoxes proposed by Zeno, the movement was erroneously deconstructed in a tight collection of parts exterior among themselves, similar to the image of the space traversed by a mobile. Even though the geometric line of the trajectory could be divisible into several different and exterior parts, the same could not be said about the movement. The instants that have gone by (or flowed) may be projected spatially, but the flowing itself of these instants, their movement or becoming, cannot. That is, the scientific thought illegitimately deconstructs the movement into a series of successive points and considers that it apprehends them on the whole, when in fact it leaves out transition, the passage, duration itself. Because intelligence naturally tends to crystallizing the moving reality into discontinuous and immobile units, Zeno's paradoxes resulted into logical paradoxes.

It's in the text 'La perception du changement', a conference presented in Oxford in May 1911, that Bergson brings forth the most didactic of all his explanations on the issue. In a captivating style, he states that the safest way to overcome

[10]PM [5], p. 3.
[11]EC [3], p. 341.

the paradoxical situation to which Zeno's arguments lead would be to interrogate Achilles himself. Once that, in fact, Achilles reaches the turtle and even overcomes it, only the testimony of the former could explain Zeno's theory. Bergson presents Achilles' decisive revelation, that is, the way as Zeno describes his race does not correspond to the way he actually runs[12]: the contradictions pointed out by Zeno refer not to the movement itself but its artificial representation by thought. Bergson states that intelligence naturally retracts in face of the anticipation of the difficulties that understanding the movement, in what it has of movable, would bring to the mind. By searching for a credible explanation, the sensorial data are as if crystallized by intelligence in fixed, stable perspectives and the uninterrupted flow of reality falls out of sight. The gravest result of Zeno's exercise consisted in the quantification of reality, forgetting the real as qualitatively indistinct and continuously fluid.

Zeno confuses two concepts that are clarified by Bergson as totally distinct dominions: the *duration* of the real movement and the *extension* of the geometrical representation of that same movement. The line that we measure is immobile, but time is mobility. Duration consists of a continuous flow where things pass and are created, by insensitive and indistinctive gradations, from one state to the other. Its representation in a spatial extension corresponds to the interruption of moving continuity and is equivalent to the suppression of the inner tension that constitutes movement. Thus, Zeno's sophisms (and all the Western metaphysics that followed) represent the opposite of what a philosophy that intends to think the inner character of movement should do, that is, the sophisms conceal the mobility that constitutes their substance.

The problem that Bergson puts to the reading that a mathematically-based science presents of time should be then put like this: how to reconstruct *what is being made* with *what is made?*[13] How to speak about the *process* in a language fit for *results* ?

If the essence of time is to flow, it cannot be put in terms of the juxtaposition of instants in space because in the exterior of the subject there is always and only one single present moment: when a moment in time is presented, none of the following ones is still in presence (or none of the preceding ones); and when those other instants present themselves, what we feel now (and all the previous ones) have passed. In time what matters is not, thus, a collection of moments registered. This register exterior to consciousness (be it in a line as the mathematical sciences do, be it in a clock or a calendar, as we do every day) only accounts for what is already done, over, dead, in a word. What matters in the discourse about real

[12]PM [5], pp. 160-161.
[13]EC [3], p. 312.

time is the mobility or transition that allows flowing from one instant to the other. Better even: the mobility which allows *creating* one instant from another.

Again Bergson's awareness of the two dimensions of time is here present: its essence while flux and while continual growth and creation. This concept of time — the *time of consciousness*, as the author refers[14] — is what is constantly making itself and is what makes everything happen. Whatever the measuring system we use, duration as an inventive and inner process being made shall never be included.

Actually, the mistake goes back to the originary structure of intelligence and to what has been previously referred to as its natural hypostasing tendency. Bergson presents a clear example: when we say, "The child becomes a man", we take childhood as a defined *state* or a thing perfectly outlined. The passage of that state to another radically different state, as the reality of adulthood, is not apprehended by thought. I.e., bestowing the attribute 'man' to the subject 'child' becomes unintelligible: when we can attribute to that subject the quality 'man', then he no longer will be a 'child', and while he is, thought cannot bestow that adjective. Reality, which in itself consists of the *transition* from childhood to mature age, vanishes in this logical impasse, since intelligence retains only the notions of 'child' and 'man' as tight frames or imaginary halts of a process. The verbal form 'becomes' [*devient*] holds an undetermined meaning and just aims at unravelling the contradiction or paradox that intelligence sees in the referred proposition. Due to the impossibility of uttering this transit that constitutes the real movement or duration, we mentally juxtapose the thing or the 'child' state to the thing or the 'adult' state, in the attempt to account for the evolution from one to the other. We compose change as a series of tight and instantaneous images and, furthermore, we take these 'pictures' to be reality itself. In Bergson's own words, *reality has slipped between our fingers*[15].

Again the famous metaphor of the cinema projector is here useful: the movement projected by this device is merely an illusion since it limits itself to juxtaposing a continuous series of photographic images so that its rapid projection mimics the real movement constitutive of the reality that these images symbolize.

It is certain that it is only because man holds the possibility to employ this illusory subterfuge of thought — treating as still things what is truly the flow of the permanent becoming — that it is possible for man to act upon what surrounds him. By occurring in the heart of a reality that is essentially movement, action requires

[14]PM [5], p. 3.
[15]EC [3], p. 312.

these *static habits of intelligence*[16] for the subject's guidance and orientation.

Nonetheless, even if our intellectual functions aim, firstly, action, when it comes to capturing real time, the time that consciousness experiences and that acts on reality, it is necessary to renounce to intelligence's proper structures, replicated by science, and access the metaphysically-based inner sense. What, in the above mentioned example, means the perception of the child that becomes man by intuition of the authentic reality, in which the syntactic subject becomes the intrinsic and substantial movement that characterises it: "There is becoming from the child to the man".

It was this intuition of duration that led Bergson to reject the scientific data as a means of perception of real time. This idea imposed itself on the philosopher with such might that enlightened all his thought in such a way that Bergson confesses to have believed that this plain enunciation would make everyone coalesce[17]. He would later find out that the condemnation of the scope of intelligence and, consequently, of the scientific knowledge of time, would be harder to accept either by scientists or by philosophers.

8.3.2 From the time of science to the time of consciousness

The time of science is, then, just a residue of true temporality generalized from a reduction of reality to a unifying sameness. Duration is hardly translated by thought in terms of our intellectual functions because it consists of a multiplicity of the qualitative or indistinctive type. Different from the quantitative numerical multiplicity, whose elements are distinguished in space, the indistinct multiplicity of duration consists, to Bergson, in a pure succession with no distinction[18].

Bergson refuses the gemination of time and space, rejecting the latter as homogeneous and empty, the exterior form of the measurable units, which contains them and allows them to be told apart. In itself, space only allows for the representation of present moments, leaving aside the previous instants (registered only in the memory of consciousness) and duration itself.

When referring to real time as duration, Bergson seeks a pure heterogeneity in which there is a succession of qualitative alterations, which interpenetrate without precise outlines and which do not exteriorise themselves mutually.

[16] Ibidem, p. 274.
[17] *Œuvres. Édition du Centenaire* [4], pp. 1543.
[18] E, p. 74 and following.

When thought illegitimately brings the idea of space into the representations of reality, it presents the several moments of the cosmic becoming simultaneously side by side. The pure succession is crystallized in a continuous line in which the different parts touch each other without interpenetrating and, as happens with the display of a clock, the before and the after are perceived simultaneously. This simultaneous level allows the ordained and distinct juxtaposition and succession of instants in space. The time of clocks, sand clocks, calendars, is the time of sciences as mechanics, astronomy or physics, time as measurable and homogeneous, a simple *space phantom*, as Bergson puts it[19].

The question must be asked then: if real time is duration and duration means the absence of all and any idea of space, for what reason thought persists in the misunderstanding of real time as a homogeneous medium where events enroll themselves?

Bergson answers by articulating time as a psychic reality and as an ontological one. That is, intelligence stains the duration with space because things outside ourselves endure as we do, being their duration irreducible to ours. Let's explain.

Outside the subject's mind, in the spatial representation of simultaneities, we find a *mutual externality without succession*, that is, the time instants measured and represented by science and by common sense constitute parts that present themselves as juxtaposed extremities without the inner connection that creates and reveals them. Inside the subject, in the inner and continuous life of consciousness, there is, on the contrary, a *succession without mutual externality*. Things thus perceived do not present themselves with defined outlines, but meet in constitutive interpenetration, composing the authentic pure succession (succession without distinction). As mutual externality without succession, science accounts for disconnected and tight extremities; as succession without mutual externality, consciousness captures the intervals of passage or time flowing. Space separates the time instants, annihilating the duration, which is passage; consciousness that endures unites the succession in the qualitative indistinctness.

However, because succession in consciousness happens at the same time as the exterior movements that seek to represent it, for example in the display of a clock, the mind has gained the habit of dividing duration in the same way as it divides its spatial extension. We are not the only ones to endure in the Universe, duration or temporal flowing pulses everywhere. Then, at the same time in which I perceive the present moment represented in the clock's display each time the hand reaches a new position, I have an inner representation of the moments that same clock hand passed and, without realizing the mistake, attribute to the procedure of measur-

[19]Ibidem, p. 80.

ing the same characteristics of consciousness' flow of inner duration. Assisted by science, intelligence geminates time and space and considers both as homogeneous media where phenomena are inscribed, eliminating mobility from movement and duration from time.

We go back to the objection that Bergson had vaguely formulated when he had studied the mechanical fundament of Spencer's theory: because the intervals of duration between the instants do not count for science, if these were two or three times quicker, nothing would change in mathematics, physics or astronomy's formulas. A close reader of the scientific literature of the epoch, Bergson here went back to the hypothesis of the universal growth of velocities, usual at the time, seeking to withdraw from it some metaphysical consequences.

In this context, Bergson understands that science showed itself impermeable to the hypothesis of universal and simultaneous acceleration of all movements of the universe, but consciousness didn't. If all the velocities of the universe were changed in the same proportion, the consciousness which accounts for the duration as a non-measurable flow would immediately apprehend the discrepancy between the exterior flow of things and the flowing of inner life.

It is, then, in the inner knowledge of consciousness (in the *intuition*, act of coincidence of consciousness with the moving reality), as an actor and spectator of that same knowledge, that real time can reveal itself.

The passage of the time of science to the time of consciousness is developed by the author in the controversial work *Durée et simultanéité*, written in 1922, and dedicated to the debate of Einstein's Relativity Theory.

8.4 The nature of real time

8.4.1 Bergson and Einstein

The relationship between Bergson and Einstein has had several interpretations, philosophical and scientific, and is regarded as an embarrassment that biographers and commentators of the French thinker have tried to explain. *Durée et Simultanéité* was published after the difficult debate which took place between both of them at the *Société Française de Philosophie* in April 1922.

Durée et Simultanéité rejected the restricted theory of relativity and took side with the unit of a real time, stating that there should be an equal time for all observers

(the time of the consciousnesses). We shall not analyse in detail or criticise Bergson physics' arguments. However, it is important to enhance that it is not as a physicist that Bergson addresses the theory of relativity, but as a philosopher. This means that his analysis and discussion of relativity did not envisage the scientific fundaments of the theory, but its metaphysical interpretation.

Far from intending to physically certify his thought on time, Bergson finds in the discussion on relativity an opportunity to rethink (and revalidate) his philosophy of duration, mainly in what concerns the relation between the experience of time and its measure. And he will conclude that Einstein had mistaken time for space and that the new theory of relativity refers to a purely mathematical temporality restricted to calculus. This time that relativity tells us about cannot be considered a *metaphysical reality* or even a *reality*, concludes Bergson, once that it is real only what is given (or can be given) in an experience; in other words, something whose existence goes beyond the level of the mathematical calculus[20].

We go back, then, to the last topic we systematised on the Bergsonian conception of time: real temporality is a singular act, that is, it states itself as cadence for a specific conscience, as duration.

According to Bergson, in the theory of relativity the Newtonian scheme of a single and absolute reference system in measuring time disappears, being replaced by a collection of equivalent systems from which the physicist should adopt one. By doing so, only the time within this reference can be considered as real, because it is experienced by the singular consciousness of that physicist. All the remaining systems will become virtual (represented only as real by mathematical calculus). It will be based on this difference between the "real physicist" and the "virtual physicists" that Bergson will reject the relativity of time, considering that real time is only the time of the real experimenter: there is only time in the system which, each time, the physicist chooses as reference[21].

The philosopher then opts for a unique real time, a fact that remains enigmatic for the Bergsonian work experts, mainly after Bergson having stated that there is not a single rhythm of duration of the consciousnesses, but multiple durations (even if the mind has the habit of, erroneously, represent a homogeneous time), and proven the irreducibility of the duration of things to our own inner duration (in the famous example of the water glass with sugar, we have to wait for the sugar lump to sink and dissolve in the water, which means that its duration cannot be reduced to mine but operates in a different rhythm). However, and as Elie During puts it, it is necessary to clarify that Bergson does not mean a return to

[20]PM [5], p. 37, n. 1.
[21]C [1], pp. 1119-1122.

the Newtonian absolute time, which would be equivalent to a mathematical time conceived homogeneously and confused in an equivocal manner with space[22].

After the 1922 debate between Bergson and Einstein, both recognised some communication flaws[23]. In 1924, two years after the debate and the year of the publication of *Durée et Simultanéité*, Bergson got involved in a polemic with a French physicist (André Metz) in the *Revue de Philosophie*, having the polemic quarrel ended with the publication of a letter by Einstein acknowledging the misunderstanding of Bergson on his interpretation of the theory of relativity. Subsequently, Bergson interdicts the reprint and translation of *Durée et Simultanéité*. Yet, it is worth mentioning that in 1934, when he publishes his last work (*La pensée et le mouvant*), Bergson restates in a footnote the positions on Einstein's theory of relativity held 10 years before[24].

8.4.2 Time as the foundation of things

Durée et Simultanéité can be seen as the most technical work written by Bergson, filled with equations and mathematical symbols, thus also being, due to that, the most intricate from the philosophical viewpoint. Nevertheless, it stands out in the author's *corpus* because it's the only one of his books that not only includes the concept of 'duration' in the title, but also dedicates a whole chapter to the nature of time. For these two reasons, it cannot be ignored.

What then is this work's contribution to the way Bergson thinks time? Essentially, it's a systematization of the author's positions and a translation of his main intuition: when thinking time, the primacy lies in the flowing and not in what flows, in the process and not in the results, in the interval and not in the instants. The things, the states, the instants, the moments are instantaneous photographs taken on a transition. The duration immediately perceived is, in this case, a kind of inner memory (not necessarily in the anthropomorphic sense, but as an elementary memory that connects two instants[25]) of the flowing itself, which prolongs the *before* into the *after*, unifies them as parts of a same movement and stops them from disappearing in the fugacity of the present[26]. In this context, we could say that duration is what allows us to construe ourselves as historical beings and that

[22]Cf. Elie During, "Bergson et la métaphysique relativiste" [6].

[23]Einstein states that Bergson had not understood him (Benrubi, *Souvenirs sur Bergson* [7], p. 82) and also Bergson stated, two years later, having been misunderstood by Einstein (C [1], p. 1122).

[24]PM [5], p. 37, n. 1.

[25]DS [2], p. 46.

[26]Ibidem, p. 41.

it is, furthermore, the fundament of our own identity.

Duration is the qualitative continuation (and non measurable or capable of being exteriorised) of what is not anymore into what still is. And the power of the 'qualitative' adjective can be explained in one more of the didactic Bergsonian images: let's listen to a melody with eyes closed, without imagining the notes that compose it drawn in the score or even the pounding of the fingers in the piano keyboard. When we perceive it as indivisible and don't isolate any of its sounds, we shall experience the pure succession, multiplicity without divisibility or qualitative multiplicity. Or even when we run our fingers through the surface of a paper sheet, again with eyes closed: it is when we open our eyes that we see the line drawn by the course our fingers took, until then (and if I don't represent that same line in my imagination) I have the inner perception of duration.

It means then that there is no time outside consciousness (even if elementary and impersonal) capable of retaining the before in the experience of the after. It is in the inner sense of the (of one) consciousness that real time can be found. This — we emphasize — does not mean that Bergson considers that time exists only for the human consciousness, since in *Durée et Simultanéité* he undoes the anthropomorphism of the notion of conscience and places it at 'the foundation of things'[27]. Now what objectively exists is the flow of the creative and continuous becoming. The instants are merely virtual halts that the thought instinctively delimits and that are analogous to the mathematical points.

In *Durée et Simultanéité* Bergson states that, besides the simultaneity of instants which allows us to tell time from a clock's display or read it in a mathematical representation, there is equally the simultaneity of flows in the several consciousnesses. Without this flow simultaneity, there would only exist the duration of each subject and it would be impossible to communicate and also scientifically represent time.

Having then admitted a plurality of durations, this could maybe be the point in which Bergson could have coalesced the physical meaning of relativity. Instead, he concludes that it is in this simultaneity of flows that is founded the equivalence established by intelligence between the inner real duration and the time externally transformed into space. And opts for the unit of a unique Time.

We come to an end by restating the interpenetration of science and philosophy as one of the qualities of Bergson's work. Acknowledging the scientific misunderstandings in works as *Durée et Simultanéité*, namely in what concerns the physical theory of relativity, is not the same as condemning the reflexive importance of Bergson's thought, neither does it impede that it carries on making us think in

[27]Ibidem, p. 47.

concepts so structuring as those of space, time and becoming, which is the main goal of this symposium. Furthermore, the Bergsonian work insists on the importance of non-scientific knowledge, metaphysical in this case, in an adequate framing of our knowledge of reality.

Be it in the moments, in his work, when he is closer to the scientific discourse, be it in his philosophical reflections, Bergson struggles to defend the universe as continuity of creative and creating change. It is in this context that duration comes up as the inventive nucleus of the continuous creation of what is qualitatively new. And it is on behalf of that inner time that endures that Bergson implements all the speculative options which give reason to his positions. Mostly those that deal with the boundaries of scientific knowledge.

Bibliography

[1] Bergson, Henri, *Correspondances*, Presses Universitaires de Frane, Paris, 2002

[2] Bergson, Henri, *Durée et Simultanéité*, édition critique sous la direction de Frédéric Worms, Presses Universitaires de France, Paris, 2009.

[3] Bergson, Henri, *L'évolution créatrice*, édition critique sous la direction de Frédéric Worms, Presses Universitaires de France, Paris, 2007.

[4] Bergson, Henri, *Œuvres. Édition du Centenaire*, textes annotés par André Robinet, Presses Universitaires de France, Paris, 1959.

[5] Bergson, Henri, *La pensée et le mouvant*, édition critique sous la direction de Frédéric Worms, Presses Universitaires de France, Paris, 2011.

[6] During, Elie, "Bergson et la métaphysique relativiste", *Annales bergsoniennes*, III, PUF, Paris, 2007, pp. 259-293.

[7] Benrubi, Isaac, *Souvenirs sur Henri Bergson*, Éditions Delachaux & Niestlé, S.A., Neuchatel/Paris, s/d.